The University of Chicago

A STUDY OF SENSORY CONTROL IN THE RAT

A DISSERTATION

SUBMITTED TO THE FACULTY

OF THE

GRADUATE SCHOOL OF ARTS AND LITERATURE

IN CANDIDACY FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

BY

FLORENCE RICHARDSON

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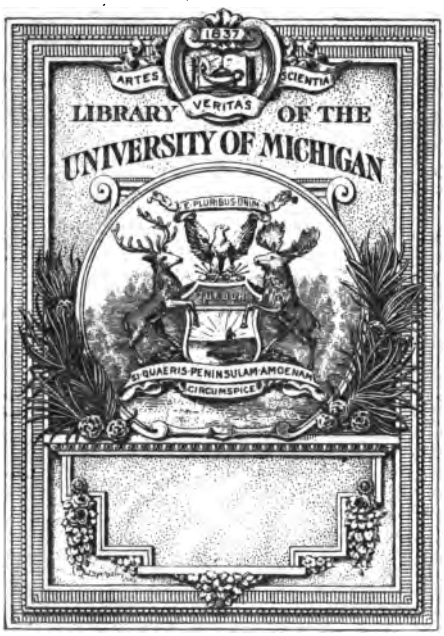

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FOUNDED BY JOHN D. ROCKEFELLER

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I desire to express here my obligation to Professor James R. Angell for constant assistance and encouragement. I am particularly indebted to Professor John B. Watson, under whose immediate direction the experimental work here presented was undertaken and carried out. My thanks are due also to Professor Harvey Carr for suggestions and criticisms of the manuscript, and to Miss Ethel Chamberlain, who assisted me during a portion of the experimentation.

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INTRODUCTION.

a. Problem and Scope of Present Study.

The work presented here grew out of a series of tests upon the rat, begun in April, 1906. Watson,[1] in an investigation which he was carrying on at the time, had found that the only necessary sensory avenues employed by the rat, in learning the maze, were the kinæsthetic and organic, and that visual, olfactory, auditory and tactual impressions could in all probability be dispensed with.

The present problem parallels that of the above investigation and may be briefly stated as an attempt to determine the function of the different sense organs in the reactions of the rat to situations requiring various types of movement. In problems like that of the maze, the general activity of running is the one most utilized. The sensori-motor arcs need only to be integrated: Whereas the coördinations which are employed in the learning of such problems[2] as Nos. I, II, and III of the present series (such as digging, bending the back and climbing upward through holes; stepping on a plane and advancing upon it until a trap door falls; raising the head and lifting a latch with the snout, etc.) are not so habitual to the animal. The sensori-motor arcs involved in the learning of these problems must be established more or less *de novo*, and at the same time be combined into a series which can function more or less automatically.

It may be assumed that since running, which is the chief form of activity involved in the maze, is so reflex-like in character, it might well be carried out by the use of kinæsthetic sensory impressions alone. The coördination involved in problems of the manipulation type, not being so reflex in character, would, if the factors involved in the formation of human habits

[1] Watson, J. B., Psych. Rev., Mon. Supp., vol. viii, no. 2, 1907.

[2] These problem boxes are described in detail further on.

may by analogy be assumed to hold in the case of the rat, require the coöperation, at first (*i. e.*, at least during the learning process), of visual and olfactory impulses, provided such were at hand. Later on such coördinations might in their turn be controlled by kinæsthetic means.

The general type of coördination in the maze, is, as has been stated, that of running. The animal, in addition, must learn what turns to make, and where to make them. Carr and Watson's [1] later report of work with a maze in which the length of the alleys may be changed, goes to show that the knowledge of the direction of the turns and the point at which they occur, is governed by the kinæsthetic and organic character of the cues for the turns. This fact explains the success of blind and anosmic rats in learning the pathway in a maze.

In Problem I of the present series, the pathway which the animal must follow is more complex than that of a maze in that it involves climbing down from the top of a box, finding a hidden entrance to the food box, digging away an obstruction, crawling under a board and up through an opening. The solution, however, is more simple than that of any of the others in that it demands little manipulation, and on the whole approaches the labyrinth type of problem. How much the guidance from vision and olfaction may assist the functionings of kinæsthetic and organic processes in the *learning* of this type of problem is one of the chief questions to be answered by the present research.

Problem II is thought to be still more difficult for the rat. The animal must learn here to press down an inclined plane at a distance from the box, and establish the association of the falling of the plane with the opening of the door of the food box. It is possible that olfaction might render the food stimulus more intense, and thereby quicken the reactions of the animal; but the question we are more concerned with is whether the olfactory values of the different parts of the environment, such as the smell of the plane, of the door of the food box, etc., aid the animal in adjusting to such situations.

[1] Jour. Comp. Neur. and Psych., vol. xviii, no. 1, 1908, p. 27ff.

Vision might also be the means by which he attains his orientation in such an open space as surrounds the apparatus.

In Problem III, the rat must raise a latch holding a door in place in order to reach the food. The area in which the successful movement must be performed is very circumscribed, being only the immediate locality of the free end of the latch. Vision may be necessary to locate the door and the latch. Olfaction may possibly play a considerable rôle here likewise.

Problem IV necessitates the rat's jumping from one platform to another in order to obtain food. It is hardly conceivable that this coördination could be successfully executed for any considerable distance without the aid of vision.

If different types of sensory control are used by the animal in meeting such different situations, the fact should become evident in a comparison of the behavior of normal rats with that of rats deprived of the use of the important sense organs.

In carrying out this investigation groups of normal white rats, normal black-and-white rats, blind rats and anosmic rats[1] were used.

During the course of the above research the experimenter collected data bearing upon the questions of sex and individual differences, and on the possible influence of previous training. While these topics were subsidiary to the main problem, the results seem of sufficient value to justify their presentation.

b. General Method.

The experiments which are here reported were as carefully controlled as possible: the tests were made every day and at the same hour of the day. Unless otherwise specified, the rats were about 120 days old when the experimentation began. This standard of age was adhered to because the rats at this time have much of the energy of youth together with fully developed neural and physiological mechanisms. Fidelity to this requirement, as may be imagined, caused the experimenter

[1] The anosmic rats, with one exception, died during the ravages of an infection which afflicted the rat laboratory. The group had only partly completed its work. On this account, the inter-comparison of the records of normal and of defective rats is not as complete as is desired.

much difficulty. A need for a group often arose when none in the laboratory satisfied the demands. This frequently meant a considerable delay until a litter of the proper age could be found. As a rule, the rats had been bred in the laboratory and were known to be of good stock. Males and females used in the work were kept in separate cages and, for the most part, were tested on separate apparatus. This was done as a check to any possible tendency toward tracking, and to minimize the emotional disturbance of fear caused by an unusual odor. The problem boxes were carefully washed and left for a time in the open air before being assigned to a new group. On account of the fact that the rats were required to get into the problem box for food, rather than to release themselves from confinement, it was necessary to inclose the area in which they were to work. A larger cage of wire netting was placed over the problem box, which is spoken of in later descriptions as the *control cage*. When an animal is confined within his problem box, no such outer cage is necessary. But unless a rat were—in a measure—confined, his insatiable curiosity would preclude a solution of his problem within reasonable time limits.

The boxes were kept covered by these cages when not in use so that no predatory wild rats could leave an odor on them. On one occasion the laboratory boy carelessly removed the control cage, and left a problem box exposed. Wild rats had evidently been about, for the next day each rat introduced into the cage became exceedingly timid with fright, and the emotional reaction was so strong and so persistent that it necessitated the abandonment of the series. Upon another occasion, when the rats which had just finished their work for the day were eating in the problem box, the experimenter killed several wild rats which had been caught in a trap. Every effort was made to remove any trace of odor from the experimenter's hands; but when the white rats were carried back to their living cages one of them seemed much frightened. The next day he objected to being handled and when put into the test cage he crouched. When he moved about at all, he slunk along close to the floor, cringing, and became quite motionless

at any loud or sharp sound. For several days his behavior suggested fear, and only after the fifth day had passed did he revert to his normal behavior. Possibly it is not necessary to go so into detail in these matters. But those who have worked with animals realize how difficult it is to maintain constant conditions. If the experimenter takes the precaution to state explicitly the methods of control in the work reported, it inspires more confidence in the minds of those who wish to utilize the results.

Milk-soaked bread, except where otherwise stated, was the food stimulus used. Hunger was relied upon as being the most constant and most natural incentive to activity. The rats were allowed to eat but sparingly of the food after the first successful efforts, but after the last trial for the day had been given they were permitted to satisfy their hunger. On the whole the method of reward was adopted as the most efficient means of controlling the reactions of these animals. The rats were never allowed to become ravenously hungry. Such a condition puts a premium upon useless and frantic movements.

The food in the problem box was always placed in the same location. The position of the food box in relation to the control cage, and of both to the points of the compass, was constant. The rat was always put into the cage at the same point and with approximately the same bodily orientation. As the entrance was at the east in the first three problems, the rat entered the control cage facing west. Particular precaution was taken in this matter, since all experiments with the rat have shown him to be very susceptible to slight changes in his environment. He has a tendency to establish a pathway from the entrance to the food box, and to follow it carefully. Unless he attains orientation quickly and pursues this pathway he becomes confused. This confusion is evidenced by the display of the same random activity present in his first trial.

Since the time records must furnish the greater part of the basis of comparison in these problems especial care was taken to maintain constant conditions. Comparisons were to be made between entire groups, and between individuals of the same or

different groups. This fact, likewise, necessitated the employment of great vigilance in experimentation.

The animals were always tame when beginning the work and were accustomed to being handled. Every group was given the different tests in the same serial order. On account of the possible influence of education, groups were not set upon the second problem without the experience of the first. While at the time the difference between the work of trained and of untrained rats was only hypothetical, the results reported here (p. 103) seem to justify the precaution.

Care in maintaining these conditions—such as the age of the rat; amount of previous training; continuous daily experimentation; and an equal number of daily trials—made the work difficult. It is admitted that even with the care taken, the conditions were not ideal. In many cases a comparison is made of tables and curves formulated from the records of groups composed of unequal numbers of individuals, and of unequal sex representation. However, the writer, at least, feels that the records obtained represent very fairly the abilities of the animals experimented upon. While much in the way of accidental variation is doubtless present, the records on the whole are reliable.

PART I

I. Experimental Results.

A. TESTS ON PROBLEM BOX I.

1. *Description of Apparatus and General Statement of Learning Process.*

The first problem box used was a modified form of the one used by Small[1] and by Watson.[2]

In this box the rat has to dig through sawdust in order to reach the entrance of the food box. The box is 30 cm. long, 22.5 cm. wide and 17.5 cm. high, the top and the bottom being of inch boards. The box is raised by supports at the corners so that the bottom is 5 cm. above the table upon which the box rests. The sides and ends of the box are covered with wire netting. The netting on the sides extends down to the table, while that on the ends goes only to the bottom of the box, leaxing an open alley under the box between the two extended side walls. In the center of the raised floor is a rectangular opening through which the rat climbs from below into the box to obtain food. This opening is 8 cm. by 10 cm. A larger opening in the top of the box, 10 cm. by 12.5 cm., allows the experimenter both to admit the food and to remove the animal from the box (see fig. I). This opening has a thin board cover which is pivoted on a screw near one of its ends.

During experimentation the sides and ends of the box were covered with sawdust to the height of the floor of the box. This height was chosen arbitrarily to insure a practically constant amount of sawdust for the animal to remove. A wire netting control cage, 52.5 cm. long, 37.5 cm. high and 37.5 cm. wide, with a door on one side, was placed over the box.

[1] Am. Jour. Psych., vol. xi., no. 2, p. 135.
[2] *Animal Education*, p. 14.

The problem with which the rat is confronted is the necessity for removing the sawdust either at the north end or at the south end of the box. Since the east and west sides are entirely covered with wire netting, movements at these points are useless. The rat must dig away a quantity of sawdust, crouch and then crawl under the floor of the food box proper, and later climb up through the hole in the floor. At the beginning of the test the animal was always placed on the top of the box facing west. It must learn to descend to the floor of the cage, orient itself as regards the north or south end of the box, and dig underneath the floor of the food box as described above. As has been stated, the pathway which the animal

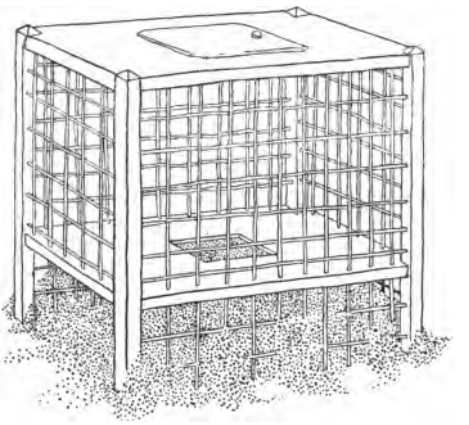


Fig. 1.

must establish is relatively simple, and, with the exception of the digging, crouching and climbing movements, the problem approaches in its simplicity that of the labyrinth type.

The above task was presented first to normal, then to defective rats in the hope of obtaining evidence for the type of sensory control utilized by the rat in forming such an association. The normal rats furnished the standard time and error record with which the records of the defective animals were compared.

The rats at work upon this problem were fed once a day for three days in the box, a handful of sawdust having previously been sprinkled over the floor to accustom them to its presence.

The time consumed during the test was taken by means of an ordinary stop-watch, which was started just after the door of the cage was closed after admitting the animal, and was stopped when the rat had all four feet in the food box.

The general description of the learning processes involved in this problem may be easily set forth by a reference to the following notes of an individual taken at random from the records of the normal rats.

Notes on the Behavior of Normal Female Rat IV in learning Problem I.

	TRIAL.	
4/20/06	1	Examined most carefully both outer cage and food box. Seemed to get odor of food and dug two-thirds length of east side. Scratched lightly at west: active but unfortunate. Began scratching at south, but gave up immediately and began at east. Dug under at west end of north side. Did not enter food box at once. Time 17.65 min.
	2	Entered at west of north, with few useless movements. Time .25 min.
	3	Entered at west of north. Time .15 min.
4/21/06	4	Scratched on east side, left, returned again to east and dug frantically, then entered from south. Time 1 .02 min.
	5	Scratched at east, entered at south. Time .15 min.
	6	Hesitated for an instant at east, but did not scratch. Time .08 min.
4/22/06	7	Entered without useless movements from the south. Time .18 min.
	8	Entered at north; dug spasmodically. Time .42 min.
	9	South. Time .17 min.
4/23/06	10	South. Time .12 min.
	11	Went to south, hesitated, seemed confused, dashed to north and in. Time .20 min.
	12	North. Time .03 min.

The above notes show many characteristic features of the learning process. The quick drop from high to low time record, which may be seen from the form of the curve, (Plate I) is typical of the first and second trials. The sudden elimination of useless movements is not always so pronounced as in the case

noted above. Often errors persist through half of the series. The manner of the elimination of errors is well illustrated in the above notes. There is at first a persevering effort to dig through at the east or west side, followed by less and less persistent endeavor at these places; later there is present only a hesitancy in passing such points, and finally, as the habit progresses, no notice of them at all.

This procedure quite parallels that of the rat in eliminating his errors in the maze. He at first explores the cul-de-sac with care, then runs into it for shorter and shorter distances, hesitates at its opening, and finally disregards it utterly. Such behavior is indicative of the early random and accidental nature of the movements, and illustrates one phase of the kinæsthetic character of control.

2. *Statement of Results.*

a. On Normal White Rats.

In order to obtain normal records with which to compare the records of defective animals, a group of eight white rats was used. These rats were 122 days old, all of one litter and were healthy, active individuals. Being bred in the laboratory their previous ancestral history was known to be of the best. Four of them were males and four were females. None had been used previously in experimentation. Table I shows the average records of this group. On Plate I the graphic representation of this average is given.

The table shows also the maximum and the minimum time records for each trial, the number of rats whose records coincide with the average for the group at that trial, and the number whose records are greater, and the number whose records are less than the average. Since average alone is not always an adequate representation of the accomplishments of a group, these few supplementary facts are added to make the average of greater value.

When the records were tabulated, the rat making the maximal and the animal making the minimal record at each trial was noted. The number of maximal and of minimal records made

TABLE I.

Showing the average, the minimum, and the maximum time-records of eight normal white rats upon Problem I. The last three columns show the number of animals whose time records are (1) equal to the average, (2) below and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM	1.	2.	3.
	min.	*min.*	*min.*			
1	7.04	3.97	17.65		6	2
2	1.69	.28	7.20		6	2
3	.48	.15	.83		4	4
4	.80	.20	1.58		3	5
5	.35	.13	.75		5	3
6	.30	.15	1.07		7	1
7	.25	.10	.55		5	3
8	.23	.10	.44		5	3
9	.27	.15	.68		5	3
10	.18	.12	.50		7	1
11	.16	.07	.30		4	4
12	.13	.13	.28		2	6
13	.15	.07	.42		6	2
14	.09	.08	.18		5	3
15	.11	.10	.22		5	3
16	14	.10	.35		5	3
17	.18	.11	.48		5	3
18	.13	.10	.20		5	3
19	.19	.07	.45		5	3
20	.09	.10	.13		4	4
21	.17	.05	.60		7	1
22	.12	.10	.33		6	2
23	.11	.10	.20		4	4
24	.23	.07	.73		7	1
25	.14	.05	.42		6	2
26	.10	.07	.20		5	3
27	.08	.05	.18		4	4
28	.12	.05	.22		4	4
29	.15	.05	.45		5	3
30	.07	.05	.13	1	3	4
31	.07	.06	.13		5	3
32	.06	.05	.09		4	4
33	.12	.05	.37		6	2
34	.17	.06	.52		5	2
35	.09	.04	.18		4	4
36	.19	.06	1.03		7	1
37	.14	.07	.50		6	2
38	.09	.07	.22		5	3

TABLE I.—Continued.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
39	.09	.07	.13	1	4	3
40	.09	.07	.45		6	2
41	.24	.08	1.33		7	1
42	.15	.06	.33		7	1
43	.12	.06	.23		6	2
44	.11	.04	.33		6	2
45	.10	.07	.32		6	2
46	.06	.03	.12		5	3
47	.06	.03	.09		6	2
48	.06	.03	.10		4	4
49	.06	.03	.10		4	4
50	.23	.08	1.26		7	1

by each individual was then given its percentage value. These percentages are shown below.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL.

Minimal Records.	*per cent.*	*Maximal Records.*	*per cent*
Male I	41.6	Male I	11
Male II	10.6	Male II	8
Male III	22.0	Male III	7
Male IV	10.6	Male IV	24
Female I	1	Female I	29
Female II	6	Female II	6
Female III	3	Female III	7
Female IV	5	Female IV	8

These supplementary tables with others similar in character will be discussed in a later section (p. 117). They are inserted here to show, in a measure, how dependent the average may be upon the variations among individuals. Male IV and Female I are responsible for more than one-half of the longest records. Male I, on the other hand, though he has not the least percentage of maximal records, has made more than two-fifths of the total number of minimal records. In other words,

he has almost as many minimal records per trial to his credit as have the other seven combined.

The last three columns of Table I were added in the hope of further clarifying the table and the curve. These columns show roughly to what extent the average represents the group. Often a high record of one individual will raise the average of the group, so that in the corresponding curve a high point is a result of the long time record of one rat. The rises in the curve at the twenty-first, thirty-fourth, thirty-sixth, forty-first and fiftieth trials are thus explained as due to the individual and probably accidental variation of some animal. On the other hand, on the sixth and tenth trials seven rats made records below the average without skewing the curve.

b. On Normal Black-and-White Rats.

A group of black-and-white rats was set to work on the series of problems. These rats were females, all of one litter, and were 112 days old when experimentation began. They had been much petted from infancy and were unusually tame.

Table II shows the time-records made by these rats and Plate I shows the graphical representation of these averages. This group, as may be seen by a glance at the curve solved the problem in uniformly less time than the normal white rats, not only with the time-records much lower on the whole but the first successes were accomplished after an exceedingly short interval.

The following table gives the percentage of minimal and of maximal time-records made by each rat.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Female I.....	51	Female I.....	16
Female II.....	13	Female II.....	18
Female III.....	27	Female III.....	25
Female IV.....	9	Female IV	41

TABLE II.

Showing the average, the minimum, and the maximum time-records of four black-and-white females upon Problem I. The last three columns show the number of animals whose time-records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
	min.	*min.*	*min.*			
1	.82	.25	1.53		2	2
2	.23	.67	.37		2	2
3	.23	.67	.52		3	1
4	.12	.07	.17		2	2
5	.76	.05	.11		3	1
6	.17	.06	.47		3	1
7	.08	.07	.12		2	2
8	.08	.05	.19		3	1
9	.13	.05	.22		2	2
10	.08	.06	.10		1	3
11	.07	.05	.10		3	1
12	.06	.05	.06		2	2
13	.07	.05	.10		2	2
14	.18	.05	.53		3	1
15	.06	.05	.09		2	2
16	.07	.05	.10		2	2
17	.10	.07	.14		2	2
18	.11	.07	.26		3	1
19	.05	.05	.06		3	1
20	.09	.04	.17		2	2
21	.05	.03	.07		2	2
22	.05	.04	.07		2	2
23	.04	.03	.05		2	2
24	.05	.03	.08		2	2
25	.05	.03	.06		2	2
26	.06	.03	.12		2	2
27	.11	.03	.35		3	1
28	.04	.03	.04		3	1
29	.04	.03	.04		1	3
30	.03	.03	.04		2	2
31	.05	.03	.10		3	1
32	.04	.04	.04		1	3
33	.04	.03	.04		2	2
34	.04	.03	.06		3	1
35	.04	.04	.05		2	2
36	.05	.03	.07		2	2
37	.06	.03	.12		3	1
38	.07	.04	.09		2	2

TABLE II.—Continued.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
39	.04	.03	.05		3	1
40	.06	.04	.12		3	1
41	.03	.02	.04		2	2
42	.06	.04	.10		2	2
43	.08	.03	.17		3	1
44	.18	.02	.63		3	1
45	.06	.05	.07		1	3
46	.04	.03	.05		2	2
47	.04	.03	.05		2	2
48	.04	.04	.04		2	2
49	.04	.03	.05		3	1
50	.03	.03	.04		1	3

c. On Blind Rats.

Nine blind rats of which four were males, and five were females, were trained on the problem.[1] The animals were about four months old and all were in excellent condition.

Table III gives the records made by eight animals of the group. A curve on Plate I shows the graphic representation of the averages given in this Table.[2]

TABLE III.

Showing the average, the minimum and the maximum time-records of eight blind rats upon Problem I. The last three columns show the number of animals whose records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3
	min.	*min.*	*min.*			
1	2.73	.48	6.41		5	3
2	.51	.25	1.00		5	3
3	.91	.23	1.97		4	4
4	.73	.17	2.45		6	2
5	1.52	1.20	8.06	1	6	1
6	.51	.10	1.42		5	3

[1] Cf. Watson, *ibid*, pp. 47 ff.

[2] The time-records of one male are not included in the average. They are unusually slow and are discussed in the paragraphs on individual differences.

TABLE III.—Continued.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	I.	2.	3.
7	.23	.12	.42	1	4	3
8	.49	.07	1.93		6	2
9	.70	.04	1.92		5	3
10	.50	.17	1.63		4	4
11	.84	.07	3.60		6	2
12	.35	.06	.63		4	4
13	.28	.07	.67		4	4
14	.49	.13	1.13		5	3
15	.28	.05	.53		4	4
16	.19	.05	.48		5	3
17	.17	.04	.42		5	3
18	1.06	.05	6.13		6	2
19	.30	.05	.83		4	4
20	.21	.05	.52		5	3
21	.45	.05	1.10		5	3
22	.24	.05	.63		6	2
23	.42	.04	1.05		5	3
24	.13	.05	.33		4	4
25	.12	.05	.23		4	4
26	.37	.07	1.12		3	5
27	.18	.09	.32		4	4
28	.15	.05	.32		4	4
29	.57	.07	3.13		7	1
30	.31	.07	.45		4	4
31	.25	.08	.52		5	3
32	.18	.05	.42		6	2
33	.15	.08	.25		5	3
34	.27	.07	.75		5	3
35	.13	.04	.30		5	3
36	.16	.05	.47		5	3
37	.23	.07	.78		4	4
38	.20	.06	.42		5	3
39	.26	.37	.87		6	2
40	.26	.05	.70		4	4
41	.16	.05	.38		3	5
42	.26	.04	1.02		6	2
43	.34	.05	1.33		6	2
44	.21	.06	.45		5	2
45	.25	.07	.92		5	3
46	.22	.47	.53		6	2
47	.18	.06	.49		6	2
48	.21	.07	.42		5	3
49	.25	.04	.83		5	3
50	.13	.04	.45		6	2

The averages in the above table are low, but lack uniformity. There was wide variation among the individuals of the group, which was noticeable not only in their time records, but in their general behavior.

The following table shows the number of minimal and of maximal time-records made by each blind rat.

TABLE SHOWING PERCENTAGES OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Male II	23	Male II	4
Male III	21	Male III	6
Male IV	6	Male IV	3
Female I	1	Female I	46
Female II	22	Female II	8
Female III	22	Female III	4
Female IV	2	Female IV	25
Female V	3	Female V	4

Female IV made one-fourth, and Female I nearly one-half of the total number of maximal records. Males II and III and Females II and III, together made 88 per cent of the minimal records.

d. On Anosmic Rats.

Since in these problems the animals at all times are in relatively close proximity to the food so that odor stimuli might affect their reactions, five anosmic males were tested upon the problem. Each had had the olfactory bulbs removed as described in detail by Watson.[1] The animals were in good condition when experimentation was begun—forty days after the loss of the bulbs—and remained so throughout the test.

Table IV gives the time-records. The graphical representation made from the average is shown in Plate I.

It seems unnecessary to comment at length on the results given in the table and curve. The effect of individual varia-

[1] *Ibid.* p. 49 ff.

Table IV.

Showing the average, the minimum and the maximum time-records of five anosmic males upon Problem I. The last three columns show the number of animals whose records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE	MINIMUM.	MAXIMUM.	1.	2.	3.
	min.	*min.*	*min.*			
1	13.27	1.62	46.30		4	1
2	.63	.25	1.98		4	1
3	.22	.13	.40		3	2
4	.32	.14	.52		3	2
5	.28	.07	.62		3	2
6	.43	.07	2.92		4	1
7	.26	.07	.50	2	2	1
8	.57	.10	2.22		4	1
9	.32	.07	.73		3	2
10	.14	.07	.23		3	2
11	.20	.07	.43		3	2
12	.31	.07	.98		4	1
13	.30	.07	.90		4	1
14	.20	.06	.37		3	2
15	.31	.06	.67		2	3
16	.36	.13	.63		3	2
17	.22	.06	.40		2	3
18	.28	.16	.50		3	2
19	.20	.07	.43		3	2
20	.24	.08	.47		3	2
21	.16	.03	.25		3	2
22	.32	.05	.78		2	3
23	.35	.07	1.05		4	1
24	.21	.05	.42		3	2
25	.14	.08	.22		3	2
26	.23	.06	.42		2	3
27	.20	.07	.37		2	3
28	.30	.07	.67		2	3
29	.27	.06	.62		2	3
30	.16	.13	.24		3	2
31	.20	.07	.42		2	3
32	.27	.05	.48		2	3
33	.29	.05	.82		4	1
34	.17	.06	.33		4	1
35	.28	.07	.70		3	2
36	.57	.04	1.60		3	2
37	.39	.05	1.18		3	2
38	.17	.04	.32		3	2

TABLE IV.—Continued.

NO. OF TRIAL	AVERAGE.	MINIMUM.	MAXIMUM.	I.	2.	3.
39	.32	.08	.63		3	2
40	.28	.08	.53		3	2
41	.27	.07	.38		2	3
42	.29	.06	.55		3	2
43	.28	.13	.42	1	2	2
44	.40	.28	.67		3	2
45	.22	.08	.38		3	2
46	.35	.08	.75		3	2
47	.25	.05	.68		3	2
48	.29	.05	.93		4	1
49	.24	.09	.43		2	2
50	.41	.07	1.13		4	1

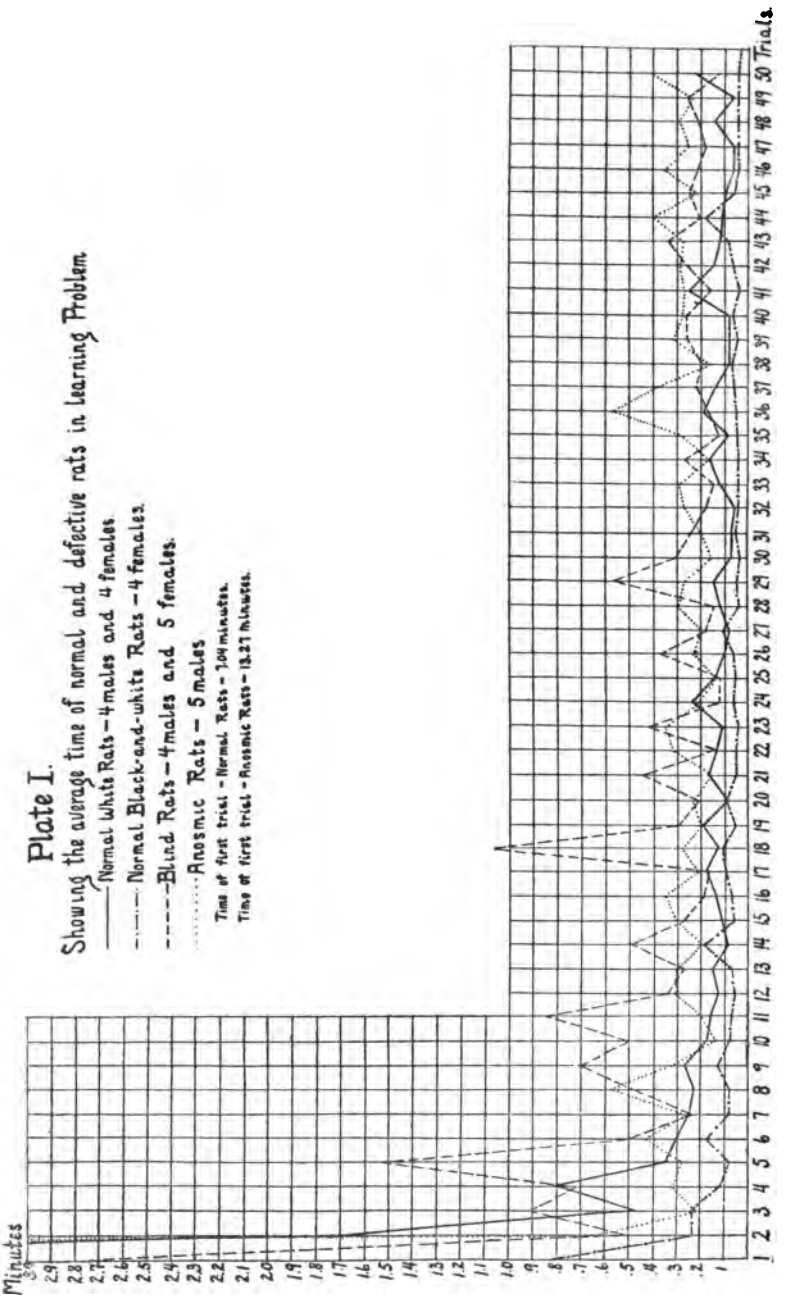
tions on the curve is roughly shown in the table below, which gives the percentage of minimal and of maximal records made by each rat.

TABLE SHOWING PERCENTAGES OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL RAT.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Male I[1]	0	Male I[1]	55
Male II	6	Male II	10
Male III	38	Male III	6
Male IV	56	Male IV	2
Male V	0	Male V	27

Male I, as is indicated, made more than one-half of the longest time-records: the time-records of Male V were also long. Were it not for the eccentricities of these two rats, the curve

[1] The emotional attitude of Male I, together with a tendency to gnaw at all that came in his way was responsible for his apparent slowness. He was a very active and hardy rat, but his efforts were entirely misdirected. He spent much of his time endeavoring to clamber from the top of the box, and once down, was more than likely to climb back up immediately and begin all over again his frantic attempts to get off. When he did spend any length of time on the floor of the cage, he vented his energy in gnawing at the outer cage, or at the wire netting of the food box. On later problems his propensity to gnaw became the despair of the experimenter, as it necessitated perpetual repairing of the apparatus. Rat V likewise spent much time in the endeavor to get off the box. He finally acquired the habit of getting off at a point nearest the door. Later, if he did not at once reach this position, he seemed utterly at a loss what to do.



for this group would have been considerably lower than it is. The records of Male IV were exceptionally short.

3. Summary.

a. Average Time-records for the Total Series of Fifty Trials.

In attempting to summarize the results of tests with different groups of rats upon this problem, only a comparison of the records made by the normal and the defective animals will be given here. The discussion of the records and a theoretical interpretation of them together with the facts brought out in later summaries will be given in the final conclusions at the end of Part I (p. 61).

The sum of the separate time-records for the entire series of fifty trials given each rat was obtained, and it was then divided by the total number of trials given that animal. This gave an average time-record for each animal on the problem and afforded one basis for the comparison of records of individuals. From the individual averages obtained as above described a group average was made which serves as an additional means of comparing the records of groups of normal rats with those of the groups of defective animals.

TABLE SHOWING GROUP AVERAGE OF THE TOTAL TIME (50 TRIALS) CONSUMED BY NORMAL AND BY DEFECTIVE RATS IN LEARNING PROBLEM.

Average Records of Groups.

	min.		*min.*
Black-and-White	.09	Blind	.49
White	.34	Anosmic	.55

Averages of Records of Individuals in the Groups.

BLACK-AND-WHITE.		WHITE.		BLIND.		ANOSMIC.	
	min.		*min.*		*min.*		*min.*
Female I	.10	Male I	.36	Female I	.11	Male I	.65
Female II	.08	Male II	.39	Female II	.42	Male II	.25
Female III	.09	Male III	.38	Female III	.24	Male III	1.09
Female IV	.08	Male IV	.27	Female IV	.47	Male IV	.17
				Female V	.32	Male V	.60
		Female I	.41	Male I	.97		
		Female II	.20	Male II	.31		
		Female III	.27	Male III	.27		
		Female IV	.46	Male IV	.27		

As may be noted in the above table the average of the group of black-and-white rats is phenomenally low as compared with that of the other groups. The individual averages of this group are very uniform. The highest individual average, which is .10 min., is just one-half of the lowest average made by any one normal white rat, viz., .20 min. The group average of the blind rats is high, but the high variations among individuals are in part responsible for the high group average. Five individual averages among the blind are lower than the group average of the normal white rats, and the lowest average of a blind rat, .24 min., is but little above that of the lowest individual of the normal white rats, .20 min. The average of the anosmic group is very slightly lower than that of the blind group, though here, too, the individual variation is high. The average made by Male II of this group is the lowest made by any normal or defective white rat upon the problem.

b. Average Time Records by Groups of Ten Trials.

The time-records of each individual were averaged by tens. The interesting fact was brought out, that of the total of twenty-six normal and defective animals, seventeen made lower averages on the second, third or fourth ten than upon the fifth. In other words: almost two-thirds of the total number of rats reached their period of highest speed early in the series of fifty trials, and later lengthened their time-records.

The average time-records by tens of the individual animals are given below. The starred averages show those instances in which the average time-record of a series of tens is shortest before the last ten of the entire series.

TABLE SHOWING AVERAGES OF TIME-RECORDS BY GROUPS OF TEN.

Black-and-white-Rats.

Individuals.

TRIALS	FEMALE I	FEMALE II	FEMALE III	FEMALE IV	GROUP
	min.	*min.*	*min.*	*min.*	*min.*
1–10	.15	.20	.26	.21	.21
11–20	.13	.06	.07	.07	.08
21–30	.06	.04*	.07	.04	.05
31–40	.05*	.05	.03*	.03*	.04*
41–50	.11	.06	.04	.04	.06

Normal White Rats.

	MALE I	MALE II	MALE III	MALE IV	AV. MALES	GROUP
	min.	*min.*	*min.*	*min.*	*min.*	*min.*
1–10	1.45	1.36	1.08	.70	1.15	1.16
11–20	.13	.16	.11*	.22	.15	.14
21–30	.09	.12	.14	.19	.13*	12*
31–40	.09	.10*	.37	.12*	.17	.15
41–50	.06	.21	.21	.13	.15	.14

	FEMALE I	FEMALE II	FEMALE III	FEMALE IV	AV. FEMALES	
min.	*min.*	*min.*	*min.*	*min.*	*min.*	
1–10	1.08	.66	.98	2.02	1.18	
11–20	.14*	.15	.12	.07	.11	
21–30	.19	.07	.16	.04	.11	
31–40	.29	.06	.06	.11	.13	
41–50	.35	.06	.05	.04	.12	

Blind Rats.

	MALE I	MALE II	MALE III	MALE IV	AV. MALES	GROUP
	min.	*min.*	*min.*	*min.*	*min.*	*min.*
1–10	1.51	.83	.65	.58	.89	.94
11–20	.33*	.26	.21	.17	.24*	.41
21–30	.80	.28	.21	.21	.37	.35
31–40	1.25	.11	.09*	.24	.42	.43
41–50	.98	.10	.16	.15	.35	.31

	FEMALE I	FEMALE II	FEMALE III	FEMALE IV	FEMALE V	AV. FEMALE
	min.	*min.*	*min.*	*min.*	*min.*	*min.*
1–10	1.53	1.50	.45	.66	.73	.97
11–20	1.38	1.17	.20	.68	.26	.54
21–30	.81	.19	.24	.30*	.16*	.34*
31–40	1.21	.14	.21	.38	.21	.43
41–50	.62	.09	.09	.33	.24	.27

Anosmic Rats.

	MALE I	MALE II	MALE III	MALE IV	MALE V	GROUP
min.	*min.*	*min.*	*min.*	*min.*	*min.*	*min.*
1–10	1.21	.30	5.00	.41	1.43	1.67
11–20	.39*	.22	.14	.15	.46	.27
21–30	.42	.29	.10	.08*	.28*	.23*
31–40	.60	.20*	.06*	.09	.50	.29
41–50	.61	.25	.14	.11	.32	.28

The occurrence of the minimum time-records early in the series may have been due to some accidental condition, such as a variation in the state of hunger. However, the behavior of the animals as well as their time-records often indicated a falling apart of the stages of the association, suggesting rather a process of dissociation, or dissolution of the association. This might be the effect of a possible decrease in the intensity of the stimulus as the reaction became automatic. The matter is commented upon here as seeming to be a situation in which an habitual coördination tends to break down through a relatively long continuance. In order to ascertain whether the rats again would lower their records for later periods of ten trials, or whether the coördination really disintegrated, the series should have been continued indefinitely, and possibly should have been controlled by changing the kind of food used as a stimulus. Lack of time prevented the continuation of this problem.

c. Discussion of Errors in this Problem.

The computation of errors which were made by the animals has been computed not upon the basis of the total number of *useless movements*, but upon that of particular kinds of random movements, namely, those by means of which a rat attempts to enter the food box from the east or west, whereas, he can only enter from the north or south. In tabulating the results, then, the attempts to dig away the sawdust at the east or west is counted an error.

The number of errors is not alone an accurate standard in the learning process of this problem. Often an error crops out in a trial late in the series after the rat has made many perfect trials. As an instance of this may be cited particularly the case of one rat, black-and-white Female IV, which made four errors, one each at her fourth trial, twelfth, thirty-fifth and thirty-eighth trial. At the thirty-fifth trial her time was somewhat longer, though at the thirty-eighth, with an error at another position, it was at her reaction time: .05 min. The scratching in these last two trials might have been a movement which was a reversion to her two early errors, or to an

accidental movement set off by contact with the sawdust at that point.

Rat IV of the anosmic group made but one error and that at the first trial. Two black-and-white females made each one error, at the sixth and ninth trials respectively.

The average number of errors for the different groups is here given.

Average Total Number of Errors.

Normal White	8.2	Blind	10.
Black-and-white	2.7	Anosmic	5.2

Average Number of Trials Characterized by Errors.

Normal White	7.2	Blind	9.7
Black-and-white	2.5	Anosmic	4.4

d. Comparison of the Curves of the Different Groups.

Plate I shows the curves plotted from the average time-records of the different groups. The curve representing the group of black-and-white rats is the lowest curve of the four. Even at the first trial, it does not rise above the coördinate representing one minute, and for most of the time it runs below that representing .1 min. The curve is not only low, but is remarkably uniform. Whether or not the lowness and uniformity is due to the fact that these rats possess pigmented eyes will be discussed in the conclusions (p. 61).

The curve representing the averages of the normal white rats approximates more nearly than any other the character of the curve representing the black-and-white rats. At the first trial this curve is much higher, and, until the fourteenth trial, does not reach so low a point as the curve of the black-and-white animals. Again at the twentieth, the twenty-seventh and the forty-fourth trials the curve goes below: otherwise, it is higher and more variable.

The curves representing the averages of the blind and the anosmic rats, respectively, are much alike and are slightly higher than those of the normal rats. Both curves are irregular, and both follow, in general, about the same level. The curve of the anosmic group is considerably lower at the third, fourth and fifth trials, than that of any other group of albino rats.

From the sixth trial these curves cross and re-cross each other continually.

B. TESTS UPON PROBLEM BOX II.

1. *Description of Apparatus and of the Learning Process.*

The apparatus used in the second test of the series consists of a box, 20 cm. by 20 cm. at the base and 15 cm. high, of wire netting of a centimeter mesh. A door, 7 cm. high by 10 cm. long, is hinged at the lower corner of one side of the box (see figure 2). A latch, on the inside is controlled by a cord passing from the latch upward through a mesh above, back over a small wooden pulley to the inclined board plane,

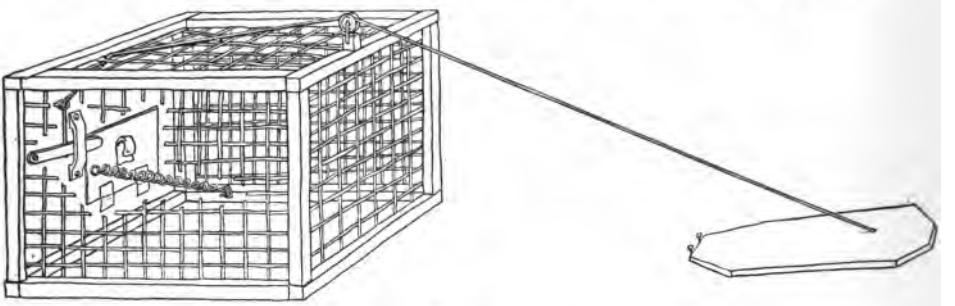


Fig. 2.

22 cm. long by 10 cm. wide, the foot of which rests at a distance of 11 cm. from the side of the box opposite the door. The angle which the plane made with the floor of the experimental cage was approximately 15°. This angle was decreased slightly when smaller animals were used.

When the rat steps upon the plane, the plane falls, and the latch is thereby pulled up allowing the door to fall inwards of its own weight. In this test there is required a series of adjustments on the part of the rat which is quite different from that demanded of him in Problem I. The question to answer is, as was the case in the learning of the problem just discussed: Does the animal use olfactory and visual impulses in the formation of these new and unusual coördinations, and if so to what extent?

The method of procedure in this test followed closely that just reported. The box was enclosed in a large wire control cage 72 cm. by 76 cm. and 37 cm. high, which could be raised when desired so as to admit the rat. The position of the box remained constant, being determined by means of several tacks in the table, which prevented the box from slipping. The plane was also kept in position by tacks at the margin nearest the box.

The animals which were used in Problem I were used in the present test. All the animals thus had had previous experience in experimentation, and this previous experience was of the same amount and kind. The results of other tests (see p. 103) show this point to be one of importance in the control of experimentation with rats. Three trials per day for ten days, and five trials per day for four days were given, making as before fifty trials in the series.

The solution of this problem is unique in that it necessitates the reaction of the rat at a distance from the food box. On this account, the learning curve from the second to about the tenth trial is much more irregular than that of Problem I. (See Plate II.) There is likely to be a second pronounced rise in the curve after the first trials. This is explained by the fact that after the first two or three accidental successes, the rat comes to associate the *position of the door with the food*, but not the *position of the plane with the food*. Consequently, the animal goes directly to the door, and finding it closed, begins to scratch and gnaw at it vigorously. This is an almost invariable procedure. The time so spent is the cause of the rise in the curve.[1]

[1] The experimenter found it necessary to secure the latch firmly during the time the rat spent tugging at the door, for when the pressure of the door was released from the latch, the weight of the plane raised the latch and allowed the rat to reach its food without performing the desired reaction. At first a hemp cord was run through a hole in the table under the box and attached to the latch. In this way the latch could be held firmly by the experimenter when necessary, and loosened at once. Later when needed a long wire slipped between the meshes of the cage and box and manipulated by the experimenter performed the same duty more surely and more easily.

An account of the procedure of one individual is given here as indicative of the learning process.

Diary Record of Black-and-White Female I on Problem Box II.

	TRIAL.	
6/5/07	1	Went at once to door of box, ran around box rapidly stopping only to sniff at food; struck the plane once, but too lightly. Gnawed industriously at door then ran about cage. Door fell at 2.33 min. without attracting her attention; she found opening at 3.07 min. and entered. Time: 3.07.
	2	Worked at door fiercely and persistently, occasionally dashed around box. Door fell at 2.00 min., in at 2.12 min.
	3	To door first, then round and round box several times. Plane fell at 1.50 min., in at 1.55 min.
6/6/07	4	Very active, but confined activity too near to box. In at once after door fell. Time: 1.78 min.
	5	Stayed too close to box. Time: 1.78 min.
	6	Had bad luck; was almost too active; jumped over plane or went around it. Door fell at 8.53 min. The rat got up on food box and spent much time in sniffing the air. Entered at 11.80 min.
6/7/07	7	Door fell at .67 min., in at .72 min.
	8	Door fell at .80 min., in at .88 min.
	9	See sixth trial. Time: 1.38 min., in at 1.50 min.
6/8/07	10	Door fell at .07 min., in at .10 min.
	11	Door fell at .03 min., in at .06 min.
	12	Rat went directly to door, then to plane, then back to door at once. Door fell at .13 min., in at .17 min.
6/11/07	18	Went as usual directly to plane and over it, but too near base, consequently door did not fall; rat then went to door, came back to plane at once, over and to the then open door. The association seems firmly fixed. Time: 18 min.

The record of this black-and-white rat was chosen because as a whole it was more typical than that of any other individual of the manner in which the association was formed, though the time records are lower than the records of an average normal rat. This rat, too, learned the problem in fewer trials than the average normal rat: indications of the *solution* were observed in the 12th trial, in which there seemed to appear

the association between the door and the plane. In this trial there were no useless movements. There was little doubt that in the eighteenth trial the association had become fixed.

The above records of the individual rat serve to call attention to the nature of the learning process involved in this test. We have (1) random movements; (2) the accidental successes from which the animal at first profits little; (3) the elimination of useless movements; and (4) the completely established habit.

The elimination of useless movements in this test is accomplished in much the same general fashion as in tests of the labyrinth type. In the former, however, the rat runs about in an open space, whereas in the latter his pathway is restricted by the side walls of the galleries. Therefore the random movements in the present case survive for a longer time than in the labyrinth, because there is greater opportunity for, and a greater variety of, them. As was stated, the rat usually goes first to the door, then about the cage and to the plane and back again to the door. Ordinarily this routine continues until about the thirtieth trial, after which the movements are in a great measure automatic.

The animals, as was stated earlier, tend in their habitual reactions to go to the plane, thence to the door by a definite route, which varies with the individual. An unusual turn in leaving the plane to go to the door may so utterly confuse them, that to run back to the plane and to start over is the only apparent manner of taking up the trail. This is a very frequent occurrence, and among the last trials is almost the sole reason for a high time record.

2. *Statement of Results.*

a. On Normal White Rats.

The group of normal white rats was first tested upon the problem.[1] The averages of the group, four males and three

[1] The problem box at the beginning of this test was not of the same form as described here. The plane was set immediately at the north end of the box, instead of 11 cm. distant, and the control cage was the small one used over Box 1, instead of the larger one later used. The original conditions made the problem much easier of solution than the experimenter desired. Radical modifica-

females,[1] are given in Table V, following the form of the previous tables. The graphical representation of the averages given in Table V is shown on Plate II.

The column showing the minimal time-records at each trial indicate how quickly the problem can be solved. For the last ten trials the minimal time runs but little over .03 minutes. The curve constructed from the group averages at the successive trials shows the second rise at the third and fourth trials, which is due to the length of time spent by the rats in going directly to the door of the box and trying to push it open.

TABLE V.

Showing the average, the minimum and the maximum time-records of seven normal white rats upon Problem II. The last three columns show the number of animals whose records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
	min.	*min.*	*min.*			
1	5.88	.25	18.56		4	3
2	1.42	.04	3.49		4	3
3	2.35	.04	9.22		5	2
4	1.54	.15	5.74		5	2
5	.80	.10	3.03		6	1
6	.72	.09	2.08		5	2
7	.95	.06	4.40		6	1
8	.27	.08	.42		5	2
9	.20	.03	.47		5	2
10	.20	.07	.37		4	3
11	.49	.63	1.20		4	3

tions were made accordingly: the plane was moved out to a distance of 11 cm. and a large control cage was put over the problem box. The rats, however, had had two days experience with the original box. The above records are all taken from tests with the modified box. It is impossible to estimate what was carried over from the old situation to the new, therefore the records may not be quite fairly comparable to those of the rats which followed; yet this fact does not detract from the utility of the curve as a whole.

[1] Female I learned to open the door, not by stepping on the plane, but by tugging at the cord which attached the plane to the latch. From about the thirtieth trial she not only tugged at the cord until the door fell, but continued to tug; so that her time-records were too variable to be included in the average.

TABLE V.—Continued.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
12	.16	.67	.47		6	1
13	.30	.67	.62		3	4
14	.12	.57	.25		4	3
15	.21	.67	.52		5	2
16	.26	.08	1.03		6	1
17	.13	.05	.20		4	3
18	.07	.05	.10		5	2
19	.14	.04	.67		6	1
20	.08	.05	.33		4	3
21	.14	.05	.50		6	1
22	.09	.04	.17		4	3
23	.12	.04	.40		5	2
24	.08	.03	.18		4	3
25	.05	.03	.10		2	5
26	.22	.04	.62		4	3
27	.13	.03	.50		6	1
28	.10	.04	.27		5	2
29	.14	.03	.33		4	3
30	.12	.03	.25		4	3
31	.18	.03	.38		5	2
32	.25	.06	1.33		6	1
33	.14	.02	.52		6	1
34	.08	.05	.18		5	2
35	.11	.07	.17	1	4	2
36	.12	.03	.25		4	3
37	.08	.04	.12	2	3	2
38	.07	.03	.10		3	4
39	.07	.04	.12	1	3	3
40	.09	.04	.23	1	5	1
41	.05	.02	.08	1	3	3
42	.19	.04	.88		6	1
43	.12	.03	.17		4	3
44	.06	.03	.10		4	3
45	.10	.03	.20	1	3	3
46	.08	.03	.16	3	2	2
47	.07	.04	.22		4	3
48	.11	.03	.22		4	3
49	.08	.03	.11	1	2	4
50	.08	.06	.13	1	4	2

The following table shows the percentage of minimal and of maximal time-records made by each of the rats in this group.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY INDIVIDUALS.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Male I	12	Male I	12
Male II	40	Male II	8
Male III	9	Male III	10
Male IV	8	Male IV	12
Female II	11	Female II	8
Female III	16	Female III	31
Female IV	4	Female IV	19

b. On Normal Black-and-White Rats.

Table VI and the curve on Plate II show the records of the group of four black-and-white females. These rats were so incessantly active that it was often quite difficult to hold them in the hand. Because of this superabundance of energy their early time-records were short. They gave evidence also, as remarked above, of having acquired the association earlier in the series than the normal white rats, whose records were unfortunately rendered ambiguous for the comparison.

After the thirty-fifth trial, the rats received a fright, probably due to the odor of wild rats about the cage. They were so disturbed upon being introduced into the problem box that the final abandonment of the series was necessitated. Their reactions had been practically constant in their last fifteen trials, so that little was lost to the experiment.

The following tabulation shows the percentage of minimal and of maximal records of each animal.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL RECORDS OF EACH INDIVIDUAL.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Female I	36	Female I	26
Female II	17	Female II	21
Female III	31	Female III	25
Female IV	16	Female IV	28

The percentage of maximal records, as indicated above, is very evenly divided among the four animals. Females I and

TABLE VI.

Showing the average, the minimum and the maximum time-records of four black-and-white females upon Problem II. The last three columns show the number of animals whose records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
	min.	*min.*	*min.*			
1	1.53	.78	3.07		3	1
2	1.70	.63	2.53		2	2
3	.73	.22	1.56		2	2
4	1.02	.70	1.57		3	1
5	1.63	.47	2.78		2	2
6	4.17	.27	11.80		3	1
7	1.10	.72	1.57		3	1
8	.87	.18	1.70		2	2
9	.90	.23	1.50	1	1	2
10	.78	.10	1.62		3	1
11	.37	.06	.92		3	1
12	.48	.17	.96		2	2
13	.28	.10	.58		2	2
14	.35	.25	.58		3	1
15	.39	.05	.67		3	1
16	.22	.11	.37		3	1
17	.30	.08	.66		3	1
18	.18	.13	.25		2	2
19	.25	.14	.35		2	2
20	.16	.13	.21		3	1
21	.15	.07	.30		3	1
22	.12	.07	.25		3	1
23	.12	.07	.20		3	1
24	.11	.06	.23		3	1
25	.07	.06	.08		2	2
26	.13	.07	.18	1	2	1
27	.14	.06	.37		3	1
28	.14	.07	.28		3	1
29	.14	.07	.30		3	1
30	.16	.09	.24		2	2
31	.11	.05	.17		2	2
32	.14	.05	.30		3	1
33	.09	.05	.14	1	2	1
34	.13	.10	.16		2	2
35	.14	.08	.18		2	2

III together made two-thirds of the entire total number of minimal records.

c. On Blind Rats.

Table VII and the corresponding curve on Plate II show similarly the average records of six[1] blind rats on Problem II.

The behavior of the blind rats was characterized by a lack of eagerness, although when first introduced into the control cage they were most anxious to get into the food box; if they were not successful soon their activity abated, and random movements characterized their efforts. They were slow in forming a pathway, and in several instances no definite path was chosen.

The percentage of minimal and of maximal time-records of forty-four trials[2] for each of the blind rats is given below.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Female I	9	Female I	38
Female II	14	Female II	26
Female III	19	Female III	7
Female IV	29	Female IV	9
Female V	22	Female V	2
Male IV	2	Male IV	18

d. On Anosmic Rats.

As before stated all but one of the anosmic rats died before the experimentation had been completed.[3] The one that remained was set to work on this problem.[4] He learned the association perfectly, but invariably pressed down the plane

[1] Males I and III had died of an infection.

[2] Female II became ill, and did not work after the forty-fourth trial, consequently the percentage after this trial is not considered. Male II manifested a decided repugnance to approaching the plane, as the falling of it had apparently frightened him; therefore he did not learn the problem.

[3] The infection became apparent just after the animals had completed their work upon Problem I, and they died almost immediately after.

[4] He was the rat which gnawed at the wire in the sawdust box.

TABLE VII.

Showing the average, the minimum and the maximum time-records of six blind rats upon Problem II. The last three columns show the number of animals whose records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
	min.	*min.*	*min.*			
1	1.32	.52	2.08		3	3
2	1.47	.23	2.75		4	2
3	4.09	.52	12.37		4	2
4	8.37	.12	45.80		5	1
5	2.37	.43	7.57		4	2
6	2.12	.30	4.03		3	2
7	3.47	.47	8.59		4	2
8	1.68	.12	4.17		4	2
9	1.93	.07	.62		4	2
10	1.70	.10	5.19		4	2
11	1.22	.12	4.33		4	2
12	2.02	.12	8.52		5	1
13	2.08	.25	8.45		4	2
14	3.34	.55	12.03		5	1
15	2.85	.22	12.67		5	1
16	1.04	.15	2.39		4	2
17	1.71	.12	4.13		4	2
18	.83	.38	1.52		4	2
19	1.22	.28	2.62		3	3
20	1.55	.38	2.33		3	3
21	1.18	.10	4.05		4	2
22	1.04	.47	1.97		4	2
23	1.35	.26	3.50		4	2
24	1.77	.28	4.67		3	3
25	.96	.28	1.87		3	3
26	1.11	.08	2.42		3	3
27	.68	.25	1.13	2	2	2
28	.48	.13	.93		4	2
29	1.04	.15	1.18		3	3
30	1.14	.18	1.58		3	3
31	2.06	.40	2.92		3	3
32	2.80	.17	15.12		5	1
33	.70	.13	1.72		4	2
34	1.41	.17	3.57		3	3
35	.08	.27	1.85		3	3
36	1.10	.32	2.67		5	1
37	1.18	.45	3.67		5	1
38	1.48	.57	1.80		4	2

TABLE VII.—Continued.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
39	1.45	.18	3.67		3	3
40	.97	.25	2.88		4	2
41	.83	.28	1.03		2	4
42	.59	.17	1.12		3	3
43	.84	.25	1.10		4	2
44	.73	.25	2.53			
45	1.11	.13	2.50			
46	1.21	.17	3.17			
47	.75	.25	1.75			
48	.40	.15	.85			
49	.63	.22	1.10			
50	.70	.18	1.52			

while gnawing the string which connected the plane with the box. When he braced himself to gnaw, the pressure of his forefeet upon the plane was instrumental in pulling up the latch. He continued to gnaw until he had completely severed the string from the plane. After the thirty-third trial he invariably ran *at once* to the door when he had finished biting at the string or plane. If he did not find the door open, he went back to the place and his gnawing, and after another effort scurried to the door again. Wire was substituted for cord, whereupon his task was seemingly endless, and he varied his procedure by dragging the plane about the cage. Table VIII shows the records of this rat. The time-records of the later trials are shown as they were taken, giving the length of time consumed by the rat in different parts of the cage.

In learning the problem, this rat did not spend the greater part of the time in the early trials—as did the rats possessed of the sense of smell—in sniffing at the food through the meshes of the wire covering of the problem box. The rat did lose much time, however, in trying to get into the box by tugging at the door.

For the first six trials the time-records of this anosmic rat—with the exception of the second—are below one minute: four of them are below .50 min. His long time-records in

TABLE VIII.

Showing the time records of the anosmic rat on Problem II.

NO. OF TRIAL.	1. BEGINS GNAWING.	2. DOOR FALLS.	3. TIME FROM PLANE TO DOOR.	IN BOX.
	min.	*min.*	*min.*	*min.*
1		.23	.20	.43
2		.75	.35	1.10
3		.20	.20	.40
4		.37	.07	.44
5		.41	.05	.46
6		.33	.63	.96
7		1.42	.63	2.05
8		3.33	1.03	4.36
9		.25	.38	.63
10		2.25	1.02	3.27
11		.28	.20	.48
12		10.66	1.33	12.00
13		.08	.08	.16
14		1.00	.12	1.12
15		.23	.35	.58
16		.48	.58	1.06
17		1.65	.73	2.38
18		1.05	.45	1.50
19		2.92	.50	3.42
20		.66	.22	.88
21		2.25	.30	2.55
22		.83	.25	1.08
23		.33	.08	.41
24		.20	.17	.37
25		1.25	.13	1.38
26		1.33	.32	1.65
27		1.25	.28	1.53
28		.22	.13	.35
29		.32	.48	.80
30		1.03	.25	1.28
31		1.80	.32	2.12
32		.92	.25	1.17
33		2.12	.53	2.67
34		.83	.15	.98
35		.22	.50	.72
36		.50	.20	.70
37	.06	1.63	.03	1.66
38	.20	.85	.05	.90
39	.08	1.42	.05	1.45
40	.05	.50	.03	.53
41	.03	1.08	.03	1.11
42	.18	1.40	.08	1.48
43	.07	.67	.03	.70
44	.20	.83	.03	.85
45	.03	.63	.02	.65

the later trials were due to his gnawing propensities. The time which he spent in going from the entrance to the plane, or from the plane to the food box was not longer than that of the average normal rat. In the last nine trials the average time from entrance to plane is .10 min., and from plane to door .04 min. Disregarding the time spent in gnawing, his average time would be .14 min., for these trials; which may by a glance at the curves be seen to be but little longer than the average time-records of the normal rat, and shorter than the maximal time-records of that group.

3. Effect on Rats of Changing Position of Plane 90° to Right.

After the group of normal white rats had completed this series, the position of the plane was changed, being placed east of the box, instead of north as before. The reactions of the animals had become practically habitual before the change was made. It was thought that the change in conditions might bring out two facts regarding the behavior of the animal: (1) The nature of the sensory control in the habitual act; (2) the nature of the sensory data by means of which the modified reaction which is necessary under the changed conditions is built up.

Since the rats in this series were put always into the cage from the east, their established pathway carried them within two or three inches of the longer side of the plane. Each of the four males was tried in turn, and each went directly to the old position of the plane, then ran to the door. One of them, Rat III, seemed confused at not finding the plane in the usual position. The other three went to the food box as though not missing the link in the series. Their confusion began at the door. Each rat, after running about in a seemingly aimless manner for a few seconds, struck the plane and the door fell. Rat I could not seem to find the way to the door, even though something connected with the falling of the plane made him frantically eager to get back to the box. He finally went over the box. On the third trial he proceeded slowly and kept his nose to the floor (discovering the plane by touch ?). From the fourth to the ninth trial he passed over the plane

directly on his way to the door. On both the ninth and tenth trials, he reverted to his old habit of going at once to the original position of the plane on the north. Rat II reverted to the old habit similarly in the ninth trial. Rat III went to the door first, except on the seventh and ninth trials when his route accidentally took him far enough south to touch the plane. The slight contact seemed to give him immediate orientation, for he ran across the plane and to the door at once.

Rat IV was the least confused. He ran to the old position but did not go to the door. Instead, he began wandering about and strayed across the plane in a seemingly haphazard fashion, but the instant it fell the old habit reasserted itself and he dashed off to the door. At the second trial he went directly across the plane to the door. All his other trials were almost precisely like his second. His records were quite phenomenally quick after the first trial, not going above .03 min.[1]

This test furnished some evidence upon the two facts sought for, i. e., the sensory avenues of control in the habitual act, and the sensory avenues of control in the process of readjustment. The habitual act seems to be carried out by means of the guidance of kinæsthetic impressions. The rats traversed the old pathway even when such movements did not lead to the successful solution of the problem. The old coördination broke down apparently in the case of these animals when they found the door closed; the fourth (Rat III) seemed to become confused in not getting the 'cue' at the plane itself. The question of the probable nature of the cue is discussed later in the section (p. 40).

[1] The case of Rat IV seems anomalous. The records bear evidence to the fact that the pathway of this rat in solving the original problem was variable. In seven out of the ten trials just preceding the change in the apparatus, the animal went first to the door, then to the plane. In the first trial after the change, he departed from his former custom of going first to the door, and instead went direct to the plane. His confusion at that point was no greater than he had often previously displayed in picking up the trails. On the second trial and on all thereafter, he resumed his old habit of going at once to the door; the result of which was that he threw the plane en-route as it was directly in his path from the entrance of the cage to the door of the food box. This explanation accounts for the seeming variation. It was simply a case in which the failure of the rat to acquire a stereotyped mode of response to the old situation made the adjustment to the new situation less difficult.

The new coördination necessary in the readjustment to the changed situation is built up on the sensory data by means of which the plane becomes the stimulus to the further coördination involved in running from the plane after it has fallen directly to the door of the food box. In these cases [*i. e.*, the inclined plane] the basis seems to be that afforded by touch. Contact with the plane was doubtless the evidence of its presence. Had some distance sense factor such as vision given the cue, it would seem that the animal would have had less difficulty in finding the plane in the new position which was at such a short distance from the old position. It was only when they came in contact with the plane that some sensory impulse connected with its fall set off the old association and they would dash to the door of the box. The new pathway was easily learned, though, as remarked above, not closely adhered to as three of the rats on later trials made errors in favor of the old pathway.

It had been a part of the plan of the work to further modify this test, but it was found later that the conditions of the learning process had not been sufficiently well controlled. In a test of this kind the rats should have learned the association in an environment every part of which was equally illuminated, so that a change in the apparatus would involve no change in brightness values in different portions of the field. The control cage should have been lined with canvas or other opaque material so as to preclude the possibility of orientation by means of distance sense factors. On this account a test involving such modifications as have been here made are not conclusive. The results are suggestive; and if the test were properly controlled it would be of value in isolating the different sense factors which function in forming the association.

A problem of especial interest which arose in carrying out the above work is that of the sensory avenue by means of which the rat obtains the cue for the run to the door after the plane has fallen. In the early trials of the test it seemed quite sufficient for the rat merely to run *past a certain point on the floor of the cage.* Indeed, many rats never appear to get beyond this method of reacting. But occasionally a rat hesi-

tates at the plane apparently until he gets a cue that the door has fallen inward. In such instances the cue may be: (1) The sound of the falling door; (2) the molecular vibrations (tactual impressions) set up in the wood by the door as it falls upon the floor of the cage; (3) the jar (kinæsthetic and possibly static) of the falling plane.

Male III was an animal which did not seem to require such a cue. Several times in the last ten trials this animal would run to a position about one inch west of the plane, rear up slightly, and assume the crouching attitude which he had been accustomed to assume on the plane itself and would then dash back to the door. He had thus gone through all the movements of throwing the plane, *except that he had not performed them on the plane.* He was completely confused when he found the door closed. This rat at least, evidently oriented himself according to the relative position of the plane. The tactual element in the experience seemed of no value while the kinæsthetic experience of raising the forepart of the body and lowering it was apparently the esssential feature. This kinæsthetic series was sufficient to set off the sequent coördinations. The failure of the animal to react to the plane itself when almost touching it and when to all appearances attempting to react to it, is typical of the earlier trials of practically all of the rats. There is no evidence whatever that the rat perceived the plane or that the plane comes to be an isolable portion of the problem box situation. A rat, when attempting to get into the food box, runs around the box in varying circles. In one of these circles he runs over the plane and when he hurries back to the door, as he does after every peregrination, he finds it open. Many such trials are necessary before he establishes a pathway which includes in its course the crossing of the plane. This seems to indicate that the reaction of the animal to the plane is determined by kinæsthetic data and that the kinæsthetic experience at this point is the stimulus for the further movement, namely, that of turning to take up the pathway to the door.

On the other hand the behavior of Male II of the same group indicates a different kind of series of stimulations at the plane.

His path led him out upon the plane, rather than across it. On his forty-fourth, forty-eighth, forty-ninth and fiftieth trials he crouched near the margin of the plane nearest the cage, but as he was not far enough away from the inner margin, his weight was not sufficient to press down the plane, and consequently he could get no report. He then took another step further out and waited. Usually the door fell after his second step. It happened once on the forty-ninth trial that a third step was necessary to press down the plane. When this step had been taken, and the door had fallen, he hurried off to the food box.

It is not easy to postulate just what happened in the case of this rat. It is evident that some form of sensory data, probably auditory, combined possibly with tactual, kinæsthetic and organic, gave the cue to the succeeding coördinations.

4. *Summary.*

a. Average Time-records for the Total Series.

The average of the total time consumed both by the individuals and the groups is given below. The group averages are given only for the first thirty-five trials, by reason of the fact that the group of black-and-white rats were unable to finish the series of fifty trials.

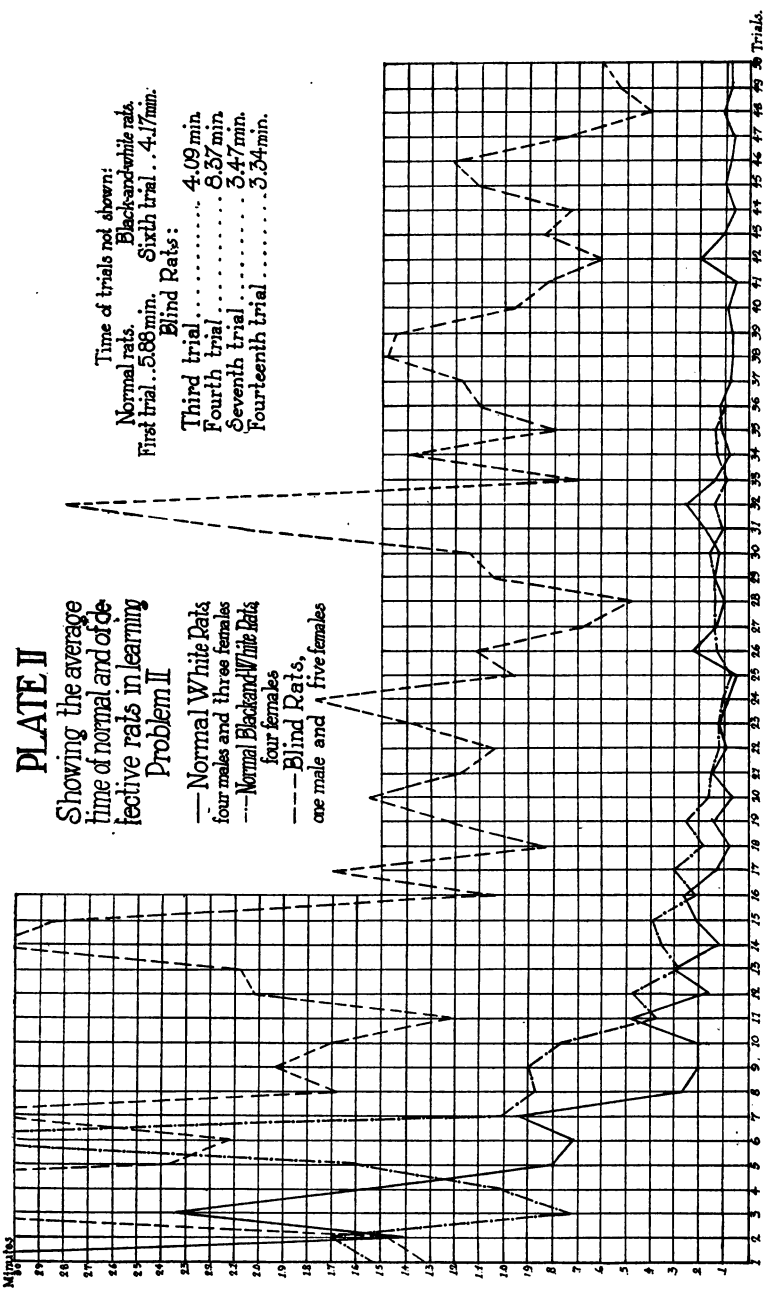
TABLE SHOWING THE GROUP AVERAGE OF THE TOTAL TIME (THIRTY-FIVE TRIALS) CONSUMED BY NORMAL AND BY DEFECTIVE RATS IN LEARNING PROBLEM II.

Average by Groups

	min.		*min.*
Normal White	.48	Blind	1.48
Normal Black-and-White	.49		

TABLE SHOWING INDIVIDUAL AVERAGES OF THE TOTAL TIME(35 TRIALS) CONSUMED BY NORMAL AND BY DEFECTIVE RATS IN LEARNING PROBLEM II.

Normal White.	*min.*	*Normal Black-and-White*	*min.*	*Blind.*	*min.*
Male I	.31	Female I	.77	Female I	1.56
Male II	.84	Female II	.44	Female II	1.67
Male III	.26	Female III	.52	Female III	1.14
Male IV	.71	Female IV	.51	Female IV	1.02
				Female V	.60
Female II	.42			Male IV	.77
Female III	.43				
Female IV	.40				



There is practically no difference in the averages of the group of the white and of the black-and-white animals. The average of the group of blind rats is much greater than that of the normal rats.

The variation among the averages of the individuals is considerable. The high records of the normal white Males II and IV, were due to high time-records in the first ten trials. The averages of the normal white females are all lower than the lowest of those of the black-and-white group. Blind Females IV and V and blind Male V, made averages lower than the maximum individual records of either the normal white or the black-and-white groups. There is greater variation among individuals of this blind group than among those of any other group.

b. Average Time-Records by Groups of Ten Trials.

The following tables show the averages of the records of the series by groups of ten trials each. The averages are given for the individuals, and for the groups. The starred records show those instances in which the minimal record for a series of ten was reached before the last series of ten.

Normal White Rats.

	INDIVIDUALS.				GROUP.
TRIALS.	MALE I.	MALE II.	MALE III.	MALE IV.	
	min.	*min.*	*min.*	*min.*	
1–10	.64	2.67	.62	2.27	
11–20	.24	.17	.08*	.08	
21–30	.10*	.05*	.13*	.05*	
31–40	.11	.05	.09	.10	
41–50	.07	.08	.13	.09	
	FEMALE I.	FEMALE II.	FEMALE III.	FEMALE IV.	
					min.
1–10		1.16	.79	.96	1.44
11–20		.10	.43	.24	.19
21–30		.12	.27	.17	.13
31–40		.09*	.28	.09	.11
41–50		.17	.17	.08	.10

Black-and-White Rats.

	FEMALE I.	FEMALE II.	FEMALE III.	FEMALE IV.	
1–1	2.28	1.03	1.19	1.19	1.42
11–20	.14	.25	.47	.32	.29
21–30	.12*	.13	.08*	.18	.13
31–35	.16	.13	.09	.09	.12

Blind Rats.

	FEMALE I.	FEMALE II.	FEMALE III.	FEMALE IV.	FEMALE V.	MALE IV.	GROUP.
1–10	2.96	.51*	1.23	8.34	1.12	2.94	2.85
11–20	4.50	.74	1.23	.69	.77	2.68	1.77
21–30	1.43	2.00	1.13*	.29*	.61	1.00	1.07*
31–40	2.81	1.99	1.28	.46	.75	.84*	1.35
41–50	1.11	1.28		.40	.57	7.80	2.23

Here, as in Problem I, many rats—in this case ten out of a total of seventeen animals—made their lowest averages before the last ten trials of the series. This peculiarity is especially noticeable in the above records of blind Female II whose first group of ten averaged considerably less than any later ten.

The blind group is the only *group* whose total average shows the minimal average by ten near the middle of the series.

c. Comparison of the Different Groups.

The curve showing the average time-records of the group of normal white rats is lowest at the first trial, from the fifth to the eleventh trials, and from the seventeenth to the twenty-fifth inclusive.

The curve of the black-and-white rats has a very pronounced rise at the sixth trial; otherwise it is more regular in contour than that of the group of the normal white rats.

The curve representing the blind rats is exceedingly high and irregular though at the first trial it is lower than any other, and at the second trial is below that of the black-and-white rats and but little above that of the normal white rats. From the eighth trial this curve does not descend to the level of the curve of the normal animal.

C. TESTS ON PROBLEM BOX III.

1. *Description of Apparatus, and of the Learning Process.*

The third problem box submitted to these same groups of rats was the familiar one necessitating the raising of a latch. As in the two previous problems, the animal enters the box for food. The box consists of a wooden frame, 14.25 cm. in height, 20 cm. in length and 20 cm. in breadth. The frame is covered with wire netting of one centimeter mesh. The spring door, 6.25 cm. high and 10 cm. wide, is so fastened to the lower left hand corner of one side of the box, that when the latch which holds the door in place is raised, the door opens outward. (See figure 3.)

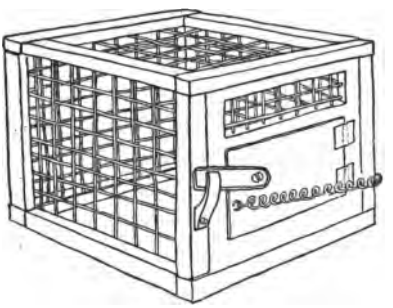


Fig. 3.

The control cage which was placed over the box is the same size as was used over Box I. A morsel of cream cheese—always of one commercial brand to insure constancy of taste and of odor—was rubbed on the back of the latch at the beginning of the series of trials. The combined taste and odor served to attract the interest of the rat, the effect of which was to lower the absolute time records of the first trials. The use of this device does not alter the general form of the learning curve, nor influence the later time records.

The unusual coördinations involved in this test are those connected with finding the door and raising the head to lift the latch. The animal may lift the latch either with its teeth, snout or claws. The rapidity of the solution depends in the

first few trials largely upon the particular type of movement adopted by the rat in opening the latch. The animal which lifts the latch with its snout is likely to make the shortest time-record, in view of the fact that this movement requires fewest muscular coördinations.

The diary notes are given as the most concise and satisfactory description of the learning process.

Notes on the Behavior of Normal Male Rat III in Learning Problem III.

	TRIAL.	
6/2/06	1	The spring interests him; stands on his hind legs and pulls it continually. While working at spring, presses down inner end of latch. Crawled in over top of door. Time: 2.20 min.
	2	Same procedure as above, but animal more active. Time: .13 min.
	3	Repeated above: Time: 1.25 min.
6/3/06	4	Leaves spring to gnaw at latch; pushes down inner end of latch as before. Time: .13 min.
	5	Raises latch with teeth. Time: .25 min.
	6	As above. Goes in *over* door each time. Time: .12 min.

This particular rat crawled either over or under the door in entering the food box until the end of the series. Most of the rats discovered the easier method of entrance, and a number of them learned to raise the latch from the left, and saved themselves the annoyance of a blow from the opening door. In a number of instances the rats became wary about entering the box on account of having been struck by the door. Many long time-records near the beginning of the series are to be explained in this manner. Individual variations in the animals' methods of solving this problem are more noticeable here than in any of the other problems.

2. *Statement of Results.*

a. On Normal White Rats.

Table IX and the curve on Plate III show the averages of the time-records of the group of normal white rats upon this problem.

The group at this time consisted of four males and two females.[1]

TABLE IX.

Showing the average, the minimum and the maximum time-records of six normal white rats on Problem III. The last three columns show the number of animals whose records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
	min.	*min.*	*min.*			
1	5.72	1.87	9.48		3	3
2	.32	.08	.55		3	3
3	.33	.02	1.25		5	1
4	.17	.10	.21		2	4
5	.29	.08	.87		4	2
6	.22	.12	.37		4	2
7	.09	.04	.14		3	3
8	.09	.05	.15	1	3	2
9	.06	.03	.08		3	3
10	.06	.03	.08		4	2
11	.07	.05	.11	1	3	2
12	.05	.03	.07	2	2	2
13	.05	.02	.07		3	3
14	.05	.04	.06	2	3	1
15	.05	.03	.08		5	1

These rats did not discover the door in the first trial; but at the second they went almost immediately to it and bit and clawed at the latch and spring with great energy. By the end of the series, each rat had learned to lift the latch with its snout, and most of them raised the latch from the outer margin and were thus out of the way of the door when it flew open. The individual records are very uniform. At the fifteenth trial the coördinations were perfect and had become habitual. The experiments were therefore discontinued.

[1]This group has been reduced in numbers. Female III died, and Female I who was slow in Problem I, slower in II, and very slow in the present problem made such uniformly poor records that they were omitted in the average, as they represented a very marked variation. She made the maximum time-record in every trial. Her time-records are given and discussed in the section on individual variations.

The following table shows the percentage of maximal and of minimal time-records made by each animal.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL.

	Minimal.		*Maximal.*
	per cent.		*per cent.*
Male I	46	Male I	0
Male II	10	Male II	0
Male III	10	Male III	13
Male IV	34	Male IV	27
Female II	0	Female II	40
Female III	0	Female III	20

Neither of the two females made a minimal record during the series, and neither Male I nor Male II made a maximal record during the series.

b. On Normal Black-and-White Rats.

This group had also been reduced in number. Females I and II died at the end of tests upon Problem Box II. Table X and the curve on Plate III show the records of the two remaining animals.

TABLE X.

Showing the Average Time-records of Two Black-and-White Rats on Problem III.

NO. OF TRIAL.	AVERAGE.	NO. OF TRIAL.	AVERAGE
	min.		*min.*
1	.99	15	.04
2	.49	16	.07
3	.12	17	.04
4	.29	18	.04
5	.09	19	.06
6	.11	20	.08
7	.07	21	.09
8	.04	22	.05
9	.08	23	.04
10	.06	24	.04
11	.14	25	.04
12	.04	26	.04
13	.05	27	.03
14	.07	28	.05

The records of these two rats are very low, and very uniform. The first successes were achieved in remarkably short time, all of the averages being below one minute. In the later trials, each rat, in its eagerness to get to the door, sometimes dashed past it, and went on around the box, thus lengthening the time-record.

The percentage of minimal and of maximal time-records made by each rat in the group is shown below.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Female III	30	Female III	70
Female IV	70	Female IV	30

c. On Blind Rats.

The behavior of the blind rats was strikingly at variance with that of the normal rat in this problem. Their time-records were long and inconstant. Practically all of the rats suffered an emotional shock from the quick opening of the door when the latch was raised. The blind animals were not alone in receiving a fright at the blow of the door. One normal rat became so cautious in his attempts to raise the latch that his efforts in going up to the latch, springing back, stepping up cautiously again, and again rebounding, came to be ludicrous in the extreme. On one occasion the unsuccessful efforts of a blind rat to raise the latch were counted. Thirty-three times she approached the latch and thirty-two times she recoiled like a tight spring! Only at the thirty-third attempt did she exert enough pressure to lift the latch, and when the door flew open she seemed paralyzed with fright for several seconds, and did not attempt to enter the box. When she finally entered she caught up a mouthful of food and ran outside to devour it. This state of high emotional tension is one cause of their poor time-records, particularly in the early trials.

The following table, Table XI, and the curve on Plate III show the time-records of the group.

TABLE XI.

Showing the average, the minimum and the maximum time-records of three blind rats on Problem III. The last three columns show the number of animals whose records are (1) equal to the average, (2) below, and (3) above the average.

NO. OF TRIAL.	AVERAGE.	MINIMUM.	MAXIMUM.	1.	2.	3.
	min.	*min.*	*min.*			
1	7.32	3.95	9.23		1	2
2	3.93	.18	9.37		2	1
3	.57	.28	.75		1	2
4	2.59	.45	6.07		2	1
5	3.79	.92	7.28		2	1
6	1.90	.22	4.95		2	1
7	1.78	.15	4.65		2	1
8	.95	.35	1.70		2	1
9	1.31	.48	2.35		2	1
10	.92	.12	1.42		1	2
11	.53	.38	.77		2	1
12	.53	.17	.80		1	2
13	.60	.20	.78		1	2
14	.30	.12	.34		1	2
15	.20	.12	.28		2	1
16	.30	.25	.35	1	1	1
17	.19	.10	.30		2	1
18	.17	.11	.23		1	2
19	.51	.20	1.13		2	1
20	.19	.07	.30		1	2
21	.28	.12	.37		1	2
22	.30	.22	.45		2	1
23	.21	.20	.35		2	1
24	23	.10	.30		1	2
25	.25	.12	.35		1	2
26	.18	.13	.25		2	1
27	.27	.23	.33		2	1
28	.14	.08	.25		2	1
29	.18	.10	.28		2	1
30	.28	.17	.38	1	1	1
31	.34	.22	.45		1	2
32	.26	.12	.35		1	2
33	.19	.08	.35		2	1
34	.36	.10	.83		2	1
35	.30	.17	.43	1	1	1
36	.29	.15	.47		2	1
37	.44	.10	.72		1	2
38	.33	.08	.55		1	2
39	.27	.05	.40		1	2
40	.23	.18	.26		1	2

The blind rats were slow in attaining their first successes, and in establishing a pathway from the entrance of the cage to the door of the food box. Several rats did not establish a definite route even after forty trials. In these cases the behavior of the animal throughout the test suggested the random activity of early trials.

The table given below shows the percentage of minimal and of maximal time-records made by each rat.

TABLE SHOWING PERCENTAGE OF MINIMAL AND OF MAXIMAL TIME-RECORDS MADE BY EACH INDIVIDUAL.

Minimal.	*per cent.*	*Maximal.*	*per cent.*
Male IV	51	Male IV	23
Female IV	34	Female IV	27
Female V	15	Female V	50

d. On Anosmic Rat.

The one remaining anosmic rat was put to work upon the problem. He learned to open the door at once, but rather than enter the food box gratified himself by gnawing away the wooden latch. He had apparently established the association by the fifth trial. His time-records are almost valueless, however, being a measure, not primarily of the length of time it took him to open the door of the food box and enter but of the time he gave himself for the demolition of the latch.

3. Effect on Rats of Changing Position of Box and Cage.

After three black-and-white males had learned this problem, the experimenter changed the position of both the control cage and the problem box. In the original experiment the entrance to the cage was on the east, and the door of the problem box upon the south. After the change, the door of the cage was to the north, and the door of the problem box was to the east. The relative positions of the entrance of the cage to the door of the problem box thus remained the same; only the absolute directions had been changed. The cage and the

enclosed problem box had been rotated through an angle of 90°. The floor of the cage was of galvanized iron sheeting, and was turned with the entire apparatus.

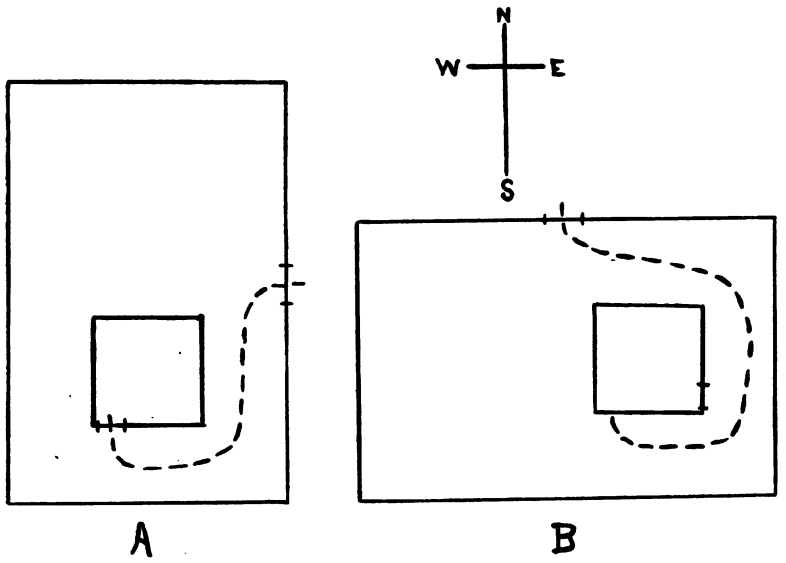


Fig. 4.

NOTE The dotted line shows the direct pathway from the entrance of the cage to the door of the problem box. Rats which have established a regular pathway use the one indicated in A. The dotted line in B, shows the lengthened pathway the rats followed after the problem box and cage had been turned.

Three normal black-and-white males had learned the problem. Their time-records had been reduced to .03 min., i. e., practically to the reaction time of the animal.

The appended diary notes describe the behavior of the animals very clearly.

Notes on Behavior of Rats with Turned Apparatus.

	TRIAL.	
1/7/08		Cage and box in first position, (A); door of problem box on south.
		Rat I.
	1	Direct to door. Time: .03 min.
	2	(Cage in changed position, door on east, 90° to right) Went to old position of door, 'nosed' the wire on south of box, became confused, went to west, back to south, strayed around close to side of the box; vibrissæ touched latch in passing; rat stopped, lifted latch, but did not enter at once. Time: .29 min.
	3	Struck door in hurrying past corner, hesitated, turned back, started on, turned back again and lifted latch. Time: .06 min.
	4	Repeated movements of trial 3. Time: .06 min.
		Rat II.
	1	(Cage in original position, (A). Time: .03 min.
	2	(Cage in changed position (B). Confused by entrance, went to west, paused at south, came back to door, (found it by snout ?), hesitated, then lifted latch and entered. Time: .31 min.
	3	Confused, went past door, hesitated, went to old position, came back, found door apparently by touch, opened it, but did not enter at once. Time: .15 min.
	4	Badly confused; wanders all about cage. Went to door in new position, 'nosed' it, but went away. Entered finally, more confused than ever. Time: .69 min.
		Rat III.
	1	(Cage in original position, (A). Went so fast he ran past door, and then came back. Time: .04 min.
	2	(Cage in changed position (*B*). Turned around and seemed utterly at a loss; went past door to south, "nosed," climbed on box and down on south, tried to raise wires again; strayed about until he came upon door, sniffed at it carefully and leisurely, went on, came back, evidently received stronger touch stimulation, then raised latch in his usual way. Time: .49 min.
	3	Passed door, turned back, hesitated, moving head from side to side, lifted latch and entered. Time: .09 min.
	4	Directly to south, then back to east. Time: .09 min.

The notes call attention to three characteristics of the animals' behavior under the new conditions: (1) The immediate excursion to the south side of the box; (2) confusion at failing to find the door; (3) nosing about to discover the door, and (4) the discovery of it made apparently in these cases at least, on the data afforded by either the contact of the vibrissæ, or of the snout with the latch or with the door. The door was not held firmly in place by the latch, but wavered slightly when an animal exerted pressure upon it with its snout or with its claws. This yielding of the door apparently often stimulates a general motor overflow which results in movements of vigorously biting and clawing at the door even before the animal associates the door with the process of procuring food. It is quite probable that as the rat searches for the entrance to the box, the yielding of the door or the mobility of the latch is the stimulus which releases the movements that raise the latch.

There was no indication that any of the rats located the door by means of vision, for each rat passed the door while 'searching' for it without reacting to it. Yet when the door was touched there followed the examination of the latch, and the performance of the requisite movements to open the door.

The next day after these tests and the second day following, these experiments were continued, with the same general results. When the door of the control cage was turned to the *north*, the rats went first to the *south*, then to the *east*, finally locating the door as before,—probably with the snout. *But each rat went first to the south, where the door had been two days before.* The old pathway involved a turn first to the left, then to the right, then to the right again. In the new position each rat lengthened his path and, after making the previous series of turns as before, added another turn to the right, arriving at the absolute spot to which his shorter path had hitherto brought him.

A blind black-and white rat was tested in the same manner, with the cage and box in the two positions. He exhibited the same characteristics as the normal rats, except that in his confusion he went *over* the food box, a habit that he had ac-

quired in learning the problem. The habit had almost disappeared, but when his first attempts were unsuccessful, he reverted to his early random movements. His time-records with the box in the changed position suffered no greater increase than those of the normal rats under the same conditions.

These tests, like those involving the changed position of the plane, were not sufficiently well controlled to justify carrying them further. The animals had learned the problem with the source of light to the west. When the apparatus was changed, the brightness values of different parts of the field were also changed, whereas they should have remained constant. In addition to this, the control cage was not large enough to permit the rat to go to the entrance to the door of the problem box without brushing the corner of the box. In this way one rat accidently discovered the latch in passing. To control the conditions properly in such an experiment, a larger control cage covered with canvas, and lighted from within, would be necessary.

The above test seems to indicate the value of touch in locating the latch. The normal rats, like the blind rat, seemed to discover the latch by contact. *The functioning of anything like discriminative vision could not be detected in the behavior of any animal submitted to these tests.* If such data had been made use of, the fact should have been apparent in the method of discovering the door. A rat when 'searching' for the door often passed it, and seemed oblivious to its location although it was not more than three inches distant.

The behavior of the animals in this experiment justifies the discussion of the behavior of rats in tests in which the position of the plane was changed (Problem II, p. 38). The contention was there advanced that there was no evidence of the perception of the plane by the rat: That the plane was not isolated from the rest of the environment. In the test with Problem III, there is no evidence that the latch or the door was singled out and reacted to as an object.

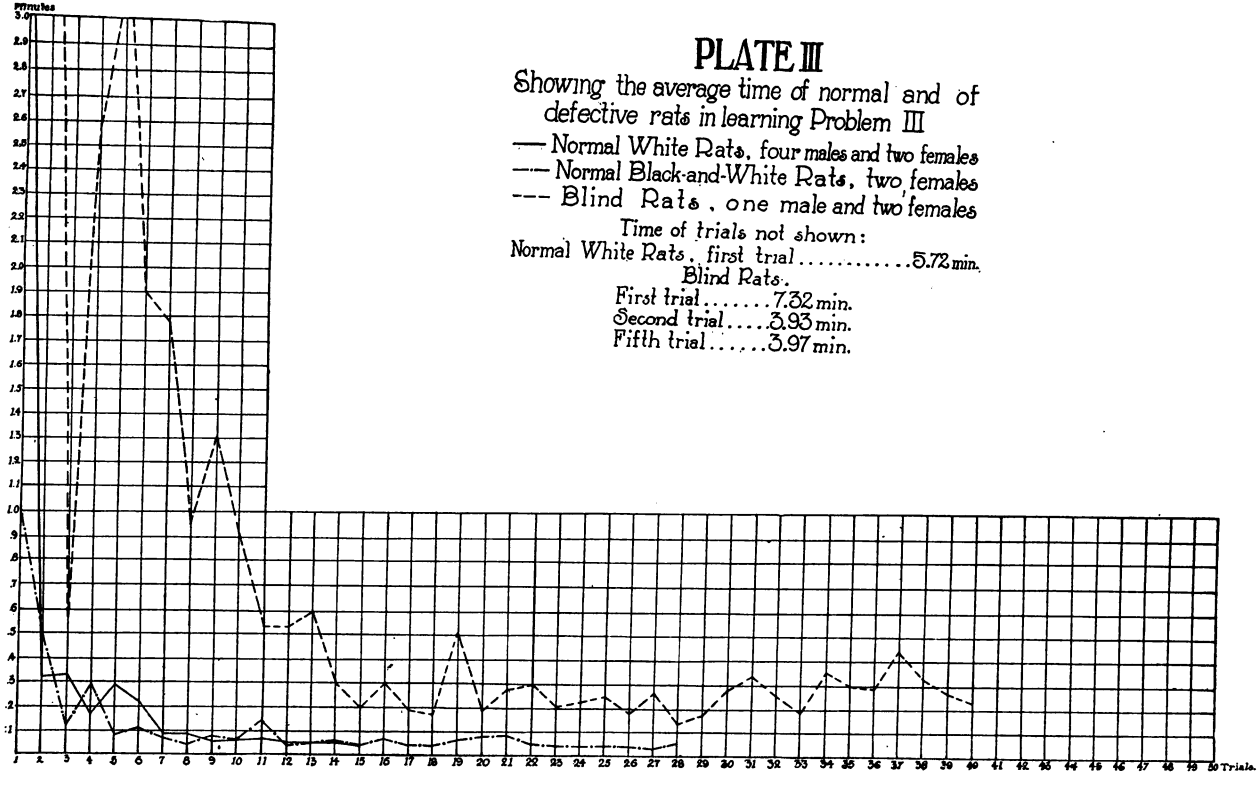


PLATE III

Showing the average time of normal and of defective rats in learning Problem III

—— Normal White Rats, four males and two females
—·— Normal Black-and-White Rats, two females
--- Blind Rats, one male and two females

Time of trials not shown:

Normal White Rats, first trial.....5.72 min.

Blind Rats.

First trial.....7.32 min.
Second trial.....3.93 min.
Fifth trial.....3.97 min.

4. *Summary.*

a. Average Time-records for the Total Series of Trials.

The following table shows the average of the total time consumed for the different groups of rats for a series of 15 trials. It has been necessary to make a comparison on the basis of this number of trials since the normal white rats, which were first tested had reached a stage of proficiency in the solution at which their reactions were constant and habitual. The later records of the other groups are given in the following section.

TABLE SHOWING GROUP AVERAGE OF THE TOTAL TIME (15 TRIALS) CONSUMED BY NORMAL AND BY DEFECTIVE ANIMALS IN LEARNING PROBLEM III.

	min.		*min.*
Normal White	.50	Blind	1.81
Black-and-White	.18		

TABLE SHOWING INDIVIDUAL AVERAGES OF TOTAL TIME CONSUMED IN FIFTEEN TRIALS.

Normal White.	*min.*	*Black-and-White.*	*min.*	*Blind.*	*min.*
Male I	.36	Female III	.24	Male IV	.63
Male II	.69	Female IV	.12	Female IV	2.95
Male III	.33			Female V	1.85
Male IV	.24				
Female II	.61				
Female III	.79				

The great difference in the group averages of the normal white and the black-and-white rat is due to the very long time-record of the white rats at the first trial. The average of the blind animals is high although the average of Blind Male IV is less than that of Normal Male II and that of Normal Female III. Unfortunately the fact that there remained but two black-and-white animals renders this group practically unavailable for purposes of comparison.

b. Average Time-records by Groups of Five Trials.

Normal White.

Individuals.

TRIALS.	MALE I.	MALE II.	MALE III.	MALE IV.	FEMALE II.	FEMALE III.	GROUP.
	min.	*min.*	*min.*	*min.*	*min.*	*min.*	*min.*
1– 5	.97	1.95	.83	.60	1.64	2.19	1.36
6–10	.08	.08	.09	.10	.12	.14	.10
11–15	.03	.05	.07	.04	.06	.05	.05

Black-and-White Rats.

	FEMALE III.	FEMALE IV.	GROUP.
	min.	*min.*	*min.*
1– 5	.60	.22	.41
6–10	.08	.06	.07
11–15	.06	.08	.07
16–20	.07	.05	.06
21–25	.05	.05	.05

Blind Rats.

TRIALS.	MALE IV.	FEMALE IV.	FEMALE V.	AVERAGE.
	min.	*min.*	*min.*	*min.*
1– 5	1.36	5.49	4.08	3.64
6–10	.26	2.76	1.10	1.37
11–15	.26	.60	.42	.43
16–20	.40	.18	.24	.27
21–25	.22	.18	.36	.25
26–30	.21	.20	.22	.21
31–36	.26	.20	1.42	.29
36–40	.31	.13	.46	.30

There is not much to be added in comment on these tables. They point out the fact that there is little or no difference in the time-records of the white and the black-and-white rats, and a very considerable difference in those of the normal and the blind rats. No blind rat made an average for ten trials in later trials so low as the highest group average for the normal rats in such trials.

Probably only the blind rats were given a sufficient number of trials in this problem to render apparent a tendency towards the dissolution of the association that has been commented on in similar records for animals on Problems I and II. Three of four of the blind rats raise their averages near the end of the series.

c. Comparison of the Curves of the Different Groups.

The curve representing the average of the normal white rats is, in this problem, more uniform than in either of the preceding problems. While the first trial is high, the curve drops very rapidly, reaching and maintaining its low level on and after the sixth trial.

The curve of the black-and-white group is much lower at the first trial, and does not make such a rapid descent, though at the fifth, sixth, seventh, and eighth trials it is lower than that of the normal white rat. At the twelfth, thirteenth, fourteenth, and fifteenth trials they run no more than .01 min. apart. The third curve, that of the blind animals, is of a different contour, as it drops much more gradually. At no point in the series of 5 trials, does it reach a level near that of either of the groups of normal rats. The curve is also quite irregular.[1]

D. DISCUSSION OF CURVES SHOWING AVERAGE TIME-RECORDS OF NORMAL AND OF DEFECTIVE RATS IN LEARNING THE MAZE.

On account of the necessity of plotting the curves shown in this paper, on a much larger scale than that employed in Watson's monograph, the difference between the blind and the normal rats seems much magnified. The time-records for the later trials on the maze rarely run below .25 min., while those on Problem I of this work go as low as .02 min. A curve constructed from data given by Watson's records[2] of the normal, blind, and anosmic animals on the maze, plotted

[1] The comparison of these curves should be supplemented by an examination of the curves obtained from the records of untrained animals on this problem. These curves are given on Plates VI and VII.

[2] Watson, *ibid.*, pp.19, 59 and 62.

on the scale here employed, is shown in Plate IV. Had the curves for the records of the rats on Problem I been plotted on the scale employed by Watson, the differences in the curves would have practically disappeared.

The curve showing the records of the normal rats is made up from the averages of four normal white males of one litter about one year old. That of the blind rats is made up of the averages of four blind males thirty-four weeks old. At no point do the time-records of the normal rats, trial by trial, go lower than that of the blind. At only two points on the curve do they go as low. The fact that they were younger and probably more active may partly account for the lower records made by the blind rats. But a comparison of the average of the blind animals with that of the nineteen, whose records go to make up the norm, shows the same low record for the blind.

Watson has formulated the conclusion that rats can learn the maze without the use of vision. The present writer has the temerity to suggest in the face of some later results that vision not only adds nothing of advantage, but may quite conceivably be detrimental to the rapidity of the learning of the maze. It has been shown that the maze may be learned almost absolutely in terms of kinæsthetic and organic impulses. Since these impulses alone are sufficient, visual impulses might be conceived of as adding a distraction.

The curve from the records of the anosmic rats is shown upon the same plate. The curve from this group runs slightly below that of the normal but above that of the blind. Here, as in the case of the blind rats, it is possible that olfactory impressions may be a stimulus to movements which in this problem are detrimental to the learning process.

E. GENERAL CONCLUSION BASED UPON RESULTS OF ABOVE TESTS.

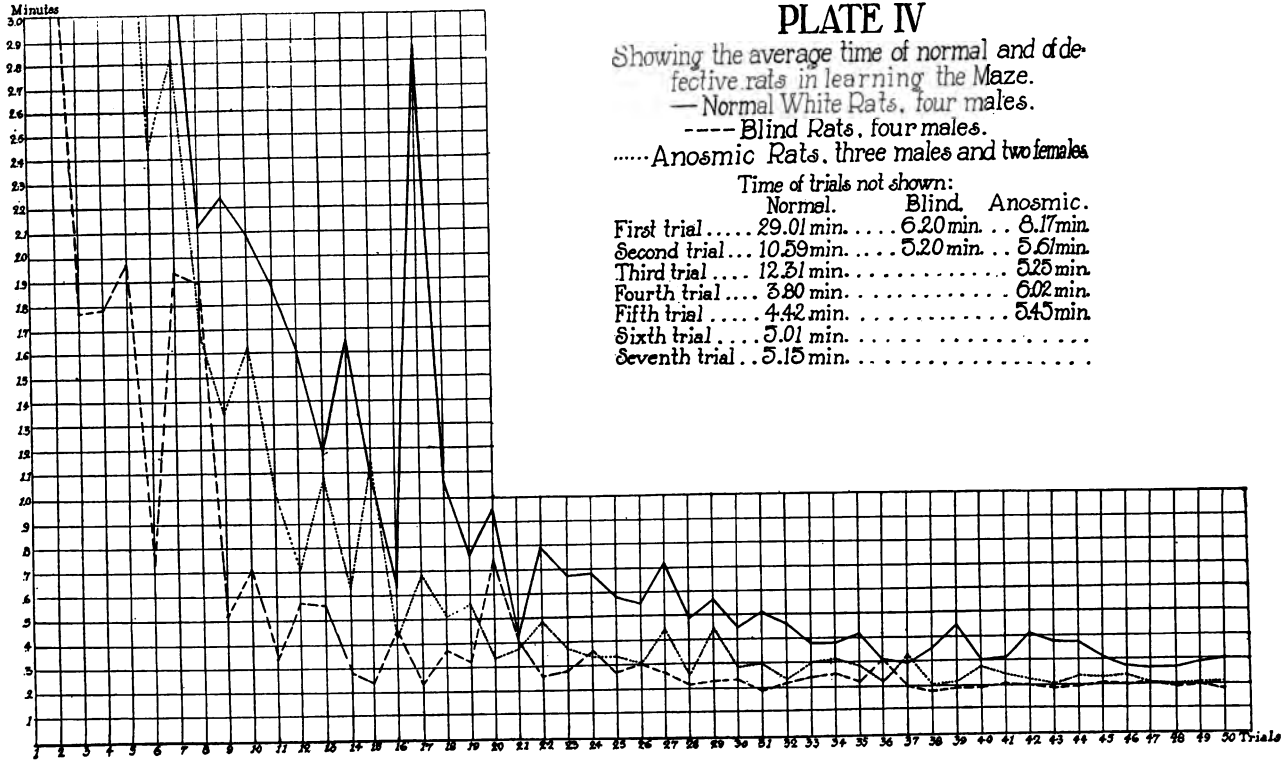
The experiment, the results of which will be reported next, is one that does not require the formation of an association such as has been required in the three foregoing experiments. Its results, therefore, will not be considered in connection with those just presented. A summary of facts will be attempted here together with a discussion of their theoretical import.

PLATE IV

Showing the average time of normal and of defective rats in learning the Maze.
— Normal White Rats, four males.
---- Blind Rats, four males.
..... Anosmic Rats, three males and two females.

Time of trials not shown:

	Normal.	Blind.	Anosmic.
First trial	29.01 min.	6.20 min.	8.17 min.
Second trial	10.59 min.	5.20 min.	5.61 min.
Third trial	12.31 min.		5.25 min.
Fourth trial	3.80 min.		6.02 min.
Fifth trial	4.42 min.		5.45 min.
Sixth trial	5.01 min.		
Seventh trial	5.15 min.		



The aim of the investigation has been to determine upon what sensory impulses the rat mainly depends in forming the various associations required in these problems. The function of the different sense processes will be taken up in detail.

I *Vision.*[1]

a. Differences in Functional Value of Vision in Rats Possessing Pigmented and those Possessing Albino Eyes.

The evidence of greater importance of vision in rats possessing pigmented eyes is, upon the whole, equivocal. In Problem I (see p. 13) the black-and-white animals made phenomenally low records; not only is the average absolute time of the group much lower than that of any other group upon this problem, but the highest individual record of the black-and-white groups, is considerably lower than the lowest average record of any normal rat. The curve representing the average of the black-and-white animals is more regular, and the individual variability is less, in this group than in any other. These facts if taken alone, would seem to indicate that the black-and-white rats were at an advantage in Problem I. In the same problem, however, the two white rats, which had had previous experience in other problems, made still lower records, (p. 103).

In Problem II there was little difference in the average

[1] The term vision up to this point has been used in the most general way. At this juncture it seems necessary to qualify its significance and to indicate the different ways in which impulses from the eye may be rendered serviceable.

1. Possibly the most primitive function of such impulses is that of heightening the general tonicity of the motor area. This hypothetical tonic effect of light impulses is referred to more extensively later.

2. White light vision implies that an animal's reactions may be modified in accordance with the brightness of visual stimuli.

3. The term color-vision implies that the animal can react in a selective way to light stimuli of different wave lengths.

4. Form-and-size-vision would be said to be present if the animal were able to discriminate the form and size of the visual stimulus to which he reacts.

5. A further possibility is depth discrimination, which in the rat may or may not involve retinal factors. One would infer the presence of this form if the animal were able to react accurately to stimuli placed at varying distance intervals in the line of vision, provided that one were certain that no other form of sensory impulse were operative.

absolute time-records of these two groups (see p. 42), although five normal white individuals made average absolute time-records lower than the lowest individual of the black-and-white group. The time-records of the normal white group—as shown in series of ten trials each (p. 44)—are uniformly lower ten by ten—than the corresponding records of the black-and-white group, while the lowest individual records in such a series were made by those having albino eyes. The time-record of the white rats was lower for the first ten trials, and the difference between that of the first and second ten was in their favor. The curve is lower for the white rats to the 25th trial, and from that point there is no advantage accruing to either group.

These facts indicate that in this problem the rats with albino eyes made slightly better records than those with pigmented eyes.

In Problem III the black-and-white rats made a much better average absolute time-record, and their individual records were lower. (See p. 32.) The tables giving the average absolute time-records in groups of 5, show a much lower average for the black-and-white rats in the first and second series of five trials each, but in the third series, the white rats made not only a lower average record, but no black-and-white individual made so low a record as that of certain individual white rats.

In the results of experimentation reported later (p. 103) a comparison may be made between the time-records of four untrained white rats, and four untrained black-and-white rats on Problem III. The untrained black-and-white animals made a lower record for the first series of five, a higher rate for the second and third series, a lower for the fourth and fifth, and a higher for the sixth.[1] As has been shown in Part II,

[1]	*Untrained white rats.*	*Untrained black-and-white rats.*
1– 5	11.12 min.	5.04 min.
6–10	.60	1.16
11–15	.21	.31
16–20	.18	.14
21–25	.10	.08
26–30	.06	.08
31–35		.05
36–40		.06

rats which have had experimental experience are much more apt in learning a new problem, presumably, largely because of less timidity during the experimentation. The black-and-white rats which made low records in Problem I were unusually tame at the beginning of the work, which probably accounts for their more rapid success. They were noticeably superior on Problems II and III.

It must be admitted after the consideration of the above data, that the evidence regarding the comparative functional value of vision in rats possessing pigmented and those which have albino eyes is not decisive.

b. Effect of Loss of Vision.

The following discussion must, in the nature of the case, deal with the effect of the *loss* of vision rather than with its explicit function when present in the normal animal. The entire series, as remarked above, afforded no opportunity for determining the exclusive function of vision. The change in conditions in the tests on Problems II and III illustrate this point: the animals did not seem to rely upon visual, but rather upon tactual and kinæsthetic stimuli, yet the blind rats were at a disadvantage as compared with the normal animals.

The least apparent difference between the blind and the normal white rats is in Problem I. The records of the normal rats, as a group, are better; the absolute average time for the white group is lower (see p. 21), although the difference between these averages of the two groups is less than the individual variations among the normal rats. The average of the absolute time for the poorest two normal males and two females (Males II, III and Females I and V, averaging .41 min.) compared with that of the best two blind males and two females (Males III, IV and Females III and V, averaging .27 min.) proves this statement conclusively. In fact, if the poorest two records of the nine blind rats be rejected, the average for the remaining seven animals is .33 min., which compares most favorably with the group average, .34 min., of the normal rats.[1]

[1] The extremely high records of the two blind animals, Male I and Female I, are responsible for the higher group average of the blind rats.

As regards the *rate* of learning, the normal rats were superior (see p. 21). The *first two* successes of the blind rats were accomplished more quickly (see Plate I) than those of the normal, though from the fifth trial to the end of the series the curves representing the normal rats is, for the greater portion of its length, below that of the blind animals.

In Problem II it may be questioned whether the blind rats formed the necessary association for the solution. But two animals, Females IV and V (see p. 42), so reduced their time-records that their individual curves approach the contour of a learning curve. The records, averaged in groups of ten, show that there is not a sufficient reduction in the time-records to warrant—on the basis of time consumed—the assumption that these rats were successful in this problem. The behavior of several of the animals at the end of the series warranted the statement that no definite path was chosen The greater variability of the group renders its average absolute time useless as a basis of comparison.[1]

A comparison of the graphs showing the average time-records of the various groups (see Plate II) suggests the doubtful justification of considering the curve of the blind animals as a learning curve at all. It must be recalled here, however, that two blind rats did arrive at the solution, though somewhat more slowly than any normal rat.

In Problem III, likewise, there is a very considerable difference in the records of the two groups. The blind rats learned to solve the problem, though the absolute time is higher throughout the series, and the rate of learning much slower (see p. 59). The individual variations as to time-records is not nearly so evident here as among these individuals on Problem II.

The differences in the results obtained in tests with blind animals, and with those which possess vision, vary with the nature of the experiment to which the two groups are subjected. Watson found that vision could be dispensed with in the learning of the maze without perceptible loss to the process. In Problem I of this series there was but little advantage

[1] Compare the average record of Blind Female II for the first ten trials with that of any other normal or defective rat.

accruing to the normal animals; in Problem III there was considerable, and in Problem II the blind animals were at a decided disadvantage. In the face of these facts it seems possible that the loss of vision is disadvantageous to the solution of these problems in proportion as the problems demand movement which, to be effective, must be definitely controlled as to the exact locality in which it is to be put forth. In the maze, the activity of the animal is definitely confined by the maze itself; namely, narrow alleys which the rat must traverse. Problem I approximates the labyrinth type in that the animal, during the solution of the problem, is somewhat restricted in its movements by the nature of the apparatus. Problem III demands movements performed within a definite area, movements unrestricted save by the motor tendencies of the animal. Problem II demands a similarly specialized movement with the added complication that the area in which the movement must be performed is at a distance from the food stimulus. Assuming that the above problems represent, in the order I, III and II a series of increasing specializations of adaptive reactions, it would seem that the loss of vision becomes more disadvantageous throughout the series.

The above tests are not of such a character as to afford unequivocal evidence concerning the possible function of vision.

The eye as previously stated affords impulses to the motor center which are presumably tonic in character. The motor impulses which are to result in general bodily movement are always conditioned by the sum of tendencies operative in the motor area. If the tonic condition of this area is low, as might be the case in blind animals, it might well happen that the requisite association would be slow in forming. It is possible in this way to account for the fact that although in their behavior these animals gave no evidence as to the function of vision the rats that through blindness may have had an insufficient energy surplus of the kind called for in these coördinations were slow in learning or failed to learn in so far as the problems demanded well concatenated activities.

2. *Olfaction.*

The group of anosmic rats made a higher average absolute time-record for Problem I (see p. 21), and the rate of learning was comparatively poor for the group as a whole. Two individuals, Males III and IV made records that were lower—in series of ten trials each—than the average of the normal group.[1] The average time for the first ten trials is particularly low for Males II and III.[2] The individual variation is high.

On Problem II the time-records of the one anosmic rat are valueless as a basis of comparison. He learned the problem, but did not solve it as the other animals had done (see p. 34).

Problem III was also learned in an eccentric fashion, which vitiated the time-records, although the association was well-formed and at the rate of the normal rat (see p. 52).

In the learning of the above problem it is not necessary for the rat to establish and follow a pathway on the basis of olfactory impressions. Such impressions may accelerate or retard the learning process; accelerate when the odor is a part of the stimulus connected with the problem box, e. g., when the stimulus releases movements which may result in the successful manipulation of the apparatus, such as clawing or biting at a latch; otherwise disadvantageous, resulting in the dispersal of 'attention,' as when the rat spends time in smelling the control cage; or, as in Problem II, in sniffing at the food, when his movements to be successful, must be performed elsewhere. This is the probable explanation of the fact that the time-records of the anosmic rats are frequently lower than the corresponding records of normal animals.

3. *Touch.*

The impulses furnished by the sense of touch seem to play an important part in the adaptation of the animal to these sev-

[1] Eliminating the record of the first ten trials of Male III, which was high because of a very long time consumed in his first success, the average of the group for the trials from 1–10, .84 min., is much lower than that of the normal rats.

[2] Compare these records with that of the blind anosmic rat, given on p. 106.

eral experimental situations. A very great difficulty arises when an attempt is made to separate the functions of the tactual from that of the kinæsthetic and organic. The tactual impulses alone, or in the complex, are the stimuli to the digging movements in Problem I, and in part to the movements of pressing down the plane in Problem II. In Problem III, certain familiar tactual impressions are evidently the stimuli to the discovery of the latch after the rat has arrived at the locality of the door. Contact *seems* also to be the cue to movements which result in raising of the latch, during both the learning process and the period in which the movements are habitual.

4. *Kinæsthetic and Allied Impressions.*

The rôle of kinæsthetic impulses in the early processes of learning probably varies in inverse proportion to the degree in which the movements must be adapted to a definite locality. Later in the process, as the movement becomes more or less automatic, the kinæsthetic and allied impulses seem to assume first importance as the means of control. In the maze such sensory impressions are sufficient. In Problem I no others were *indispensable* to a rapid establishment of the requisite associations. In Problem III, it was evident that vision could be profitably dispensed with in proportion as the reactions became automatic. In Problem II these impressions resulting from muscular activity were not only essential in the following of the pathway, but seemed also to be of service in giving the cue for the excursion to the door of the food box after the plane had been successfully lowered.

F. PROBLEM IV.

1. *Description of Apparatus and of Method of Teaching Rats to Jump.*

The three foregoing problems have been solved—though with varying degrees of success by the blind rats—by means of an evident reliance mainly upon kinæsthetic and tactual stimuli. The necessity remained to devise a problem in which

at first sight it would seem that vision *must* be the only, or at least the esssential, means of control.

Dr. Carr, when working with rats on the maze, used one rat which jumped from his hand to the table, although the next day the rat jumped in the direction of the maze but struck the floor. Two black-and-white rats which worked upon Problem I, in their anxiety to get food, acquired the habit of jumping from the experimenter's hand into the open door of the cage, a distance often of six or eight inches. These observations suggested the construction of a piece of apparatus which would necessitate *jumping* as a means of obtaining food. It would seem that in such an activity vision would be essential for successful coördination.

It is conceivable, however, that the stimulus which leads the animals to jump from one platform to the other may come through one or more of three pathways: (1) visual, (2) olfactory, (3) tactual and kinæsthetic. Factors 1 and 2 alone would be adequate to control the direction and distance of the first jump. Factor 3 might cause jumping to occur, but only after some experience of consequence would it serve to control the distance and direction of the leap. Under the conditions of the experiments here considered, it was possible to eliminate contact as a means of sensory control by keeping the tactual conditions constant throughout all the experiments. The attempt to eliminate the kinæsthetic factor was made by varying irregularly the distance between the two platforms. Smell was eliminated by the use of anosmic animals, by keeping the apparatus clean, and by control experiments upon the normal animals in which no food was given until after the jump had been taken. It was thought that the rôle of vision, the remaining factor, could be determined by comparing the behavior of the normal animals with that of the blind. In view of the fact, however, that the normal animals were so deficient in the ability to control their movements when the distance between the platforms was altered, the experiments are not decisive as regards determining the nature of the rôle which vision plays.

The factors involved in this coördination are so delicate

and so complex that the time allotted to it was not sufficient to answer all the questions which arose. Indeed, the experimenter feels that many of the questions which are here tentatively answered must be supported by a much larger group of facts before they should have anything like scientific assent.

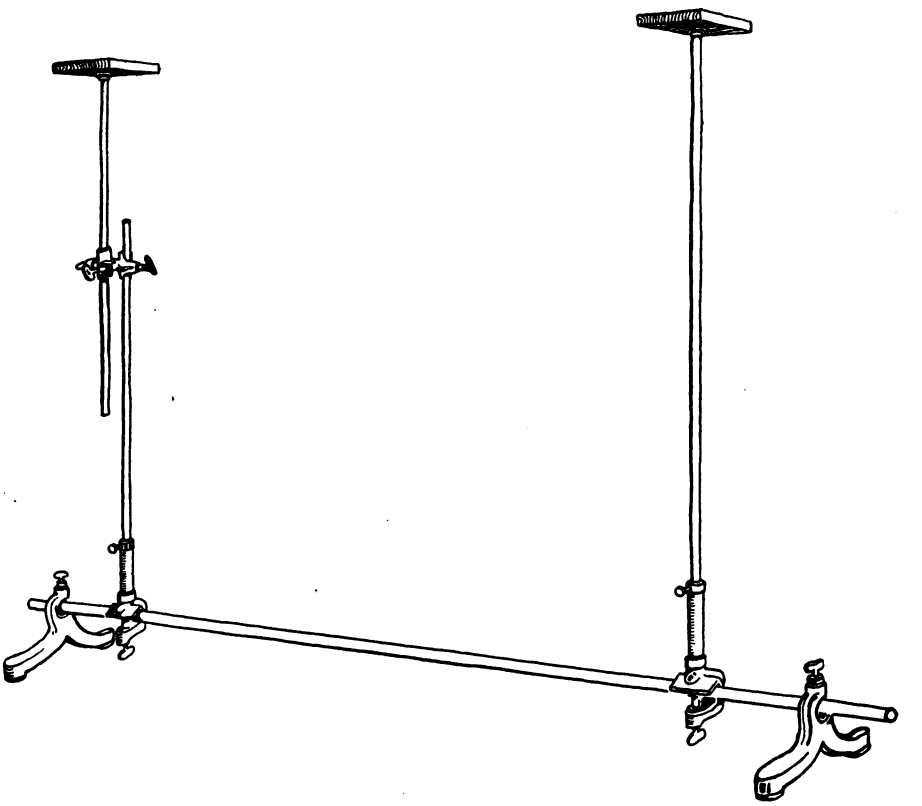


FIGURE 5. SHOWING THE MODIFIED FORM OF THE APPARATUS.

The first apparatus used in this experiment consisted of two 2 inch by 2 inch wooden uprights 20 inches high, each surmounted by a 5 inch by 5 inch platform of 1 inch board. The uprights were attached below to a 4 foot length of 2 inch by 2 inch timber, supported by wooden legs. One of the uprights was fixed, the other movable. The distance between the plat-

forms[1] might be varied from 0 to 40 inches. The entire apparatus was painted white.

The first group of rats consisted of four normal white males. Their exact ages were unknown, but were estimated about 180 days. They had been used previously for three weeks in tests upon the maze, and were accustomed to being handled. Since time-records were not sought here, but information about the delicacy of functioning of such visual-motor adjustments as would be required in jumping coördinations, the age and the training of the rats were not matters of concern.

These animals had learned to jump from the experimenter's hand to the open door of the cage, and had accomplished these feats at varying distances up to 12 inches. When they were put to work upon the apparatus, they had acquired the coördinations for short distances. These coördinations are not common to rats held in captivity. They do make short leaps in springing to and from the wire sides of their cages, but any such long jumps as they had to accomplish in these tests are entirely foreign to their usual habits. In the majority of cases the difficulty and slowness of the training was distressing to the experimenter, though in several instances the ease with which the jumping coördinations were acquired was surprising.

Most of the animals were emotionally disturbed by the conditions of the experiments; in three cases a fall so frightened the animals that they refused for a time to react in later tests.

The method of teaching the rats to jump was ordinarily laborious. The apparatus was placed in the middle of the floor in such a position that the rats were forced to jump toward the east. The platforms were placed at a distance of four inches apart. The rats were coaxed across with a morsel of food. Platform II was within reach of the animal's nose and the step across was usually taken without hesitation. After each successful effort the animal was allowed to eat a trifling amount of food. When the rats had become accustomed to stepping across, the distance between the platforms was gradually increased one inch at a time. Up to a certain

[1] The platform upon which the food was placed and *to* which the rat jumps will be designated as Platform II: the one *from* which it jumps as Platform I.

distance the rat was able to step across with little difficulty, and contact of the snout or vibrissæ with Platform II seemed to be the essential stimulus in the majority of cases.

The difficulties began when the distance was increased until Platform II was out of the reach of the rat's snout or vibrissæ. Here a double complication arose: (1) The old contact stimulus was lacking; and (2) there was the necessity for making a springing movement, in which at one instant, all four feet are without support. Several rats had no difficulty at this point; some had great difficulty; but eventually they learned to make the muscular adjustment required for the leap. Three defective rats—after many hours of coaxing—utterly failed to make the coördination. The following notes show in detail the typical behavior of a normal rat while learning to jump.

Diary Notes on Behavior of Normal White Rat III (Female) in Learning to Jump.

	INCHES.	TRIALS.	
11/30/07			Fed on platform. Small, frail, but active rat.
12/1/07	4	5	All good.
	5	5	All good.
	6	5	All good.
12/2/07	5	5	All good.
	6	5	All good.
	7	5	On first trial she scrambled slightly;[1] other trials good.
	8	5	First trial, struck slightly toward north side of platform, second trial, on south side of platform, other trials good.
	9	5	All good.
	10	5	Scrambled on first trial, others perfect.
	11	5	Scrambled on first trial.
12/3/07	8	1	Went clear over platform.
	9	5	Perfect.
	10	5	First trial a slight scramble, others perfect.
	11	5	Similar behavior.

[1] The phrase 'scrambled slightly' is descriptive of those trials in which the rat landed with the hind feet off the upper surface and against the side of the platform. The word 'scrambled' indicates that the rat landed with the fore feet, but not the hind feet on the platform, and scrambled on. If the rat could not climb on *easily*, the result was noted as 'short.'

	INCHES.	TRIALS.	
12/4/07	9	1	Perfect.
	10	5	Perfect.
	11	5	Perfect.
	12	5	Perfect.
	13	5	First and fourth trials scrambled, three perfect.
	14	5	Scrambled on second trial, others perfect.
12/5/07	11	5	Perfect.
	12	3	First trial landed with heels on edge, but struck squarely.
	14	4	First and second trials, scrambled slightly.
	15	4	First trial short, others perfect.
12/6/07	10	1	Went clear over.
	12	1	Struck squarely but with great force.
	14	1	Perfect.
	15	1	Perfect.
	16	1	Perfect.
	18	3	First trial scrambled, others perfect.
	20	4	As above.
	22	6	Second trial, landed south of platform. Third trial, struck north of platform. In these long jumps she landed with such force that she was almost breathless for several seconds afterward.
12/7/07	16	1	Would have slid off east side platform if experimenter had not caught her.
	18	1	Same procedure as above.
	20	1	Again the same.

This rat was not tested at distances greater than 22 inches. Rats I and II, which were larger animals, had learned to make longer jumps. Their records for trials greater than this distance are given below.

Rat II.

	INCHES	TRIALS.	
8/20/07	22	10	First and sixth trials, a little short. On other trials he slid across platform and nearly went off.
8/21/07	24	10	First, short; third, fourth and eighth scrambled. (His foot was sore.) Second trial overshot; fourth, to north side.
8/21/07	24	10	First, short; second, overshot; third and fourth, to north side of platform; eighth, struck squarely, but had too much momentum and slid off.
	26	5	First, scrambled; second, slightly long; fifth short.
	28	5	Third, short; fifth, overshot. (Foot was sore, discontinued tests for the present.)

Rat III.

8/23/07	22	10	Third and sixth trials, scrambled.
	24	10	First, short; second, scrambled; third, low.
8/24/07	26	10	Second trial, struck north side of platform; fourth, slightly short and to south; ninth, overshot.
	28	10	Second trial, slightly long; fourth, scrambled; others perfect.
	30	10	Second, fourth and sixth trials, low; rat had begun jumping downwards. Was apparently not aiming at platform.

The notes mention several characteristic features of the learning process: The 'scramble' on the first trials for lengthened distances; the over-innervation for shortened distances; and the frequent compensations for errors, as when the rat landed on the south side of the platform on one trial, it struck upon the north side on the next trial.[1] This characteristic is referred to in the discussion of a later test.

[1] The experimenter attempted to devise some means whereby an objective measurement of the rat's coördination could be taken. If the records could have been obtained of the exact point at which the fore feet first came in contact with the plaform, a curve could be plotted showing the accuracy of the adjustment. A cloth, marked in black and white squares 1 cm. in size, was carefully tacked over the top of Platform II. The experimenter endeavored to note the lines

2. *Jumping in Constant Direction, i. e., Apparatus in East-West Position.*

1. Statement of Results.

a. On Normal White Rats.

The results of the tests on the four normal white rats has been sufficiently discussed in the description of the learning process in the foregoing paragraphs. Each rat learned to jump the distances up to and including 22 inches. One had jumped 28 inches with considerable accuracy: one other had made eight perfect coördinations out of a possible ten at this distance, and seven out of a possible ten at 30 inches.

Three other rats learned to jump. One of them, a small male, learned to jump a distance of 22 inches in eleven days, but was slow for several days thereafter. A second, the best of the entire group at the first trials, learned in two days to jump 15 inches, then began to hesitate and finally refused to take such long distances. A third rat easily attained a distance of 12 inches, after five days training, but the later learning process was retarded by emotional factors, the results evidently of a fall on the third day of the tests. Eventually after five weeks of constant training, he jumped 22 inches, but with an average of only 50 per cent of accurate adjustments.

b. On Normal Black-and-White Rats.

Three female black-and-white rats were employed in the experimentation. Two of them were animals which had been used in the series of previous problems. Each did exceptionally well, both in learning to jump, and in the accommodation to changed conditions of the experiment. The third rat was the mother of the above two, an extraordinarily energetic animal, and one without fear. Her records on this problem—the only one she attempted—are little short of phenomenal. She was placed on Platform I at a distance of five inches from the food

upon which the rat alighted, but the movements were so quick, and the rat so often slid along by reason of his momentum, that the attempt was a failure. The use of smoked paper was likewise out of the question, as the resulting imprint was only a large erasure of the lampblack.

platform. She stepped across at once. The distance was increased to 6 inches and she did not hesitate. She jumped sixty times within an hour on her first day with but one error; these trials included five at 14 inches. Her complete record is given below.

Black-and-White Rat Number III.

	INCHES.	TRIALS.	
11/14/07	5	5	First day. Had never been placed upon platform before. Stepped across immediately.
	6	10	All trials perfect; jumped across at once.
	7	10	Perfect. The most active rat we ever knew.
	8	10	Perfect.
	9	5	Struck platform squarely every trial and always jumped immediately when she was returned to Platform 1.
	10	5	All trials perfect.
	11	5	All trials perfect.
	12	5	All trials perfect.
	13	5	All trials perfect.
	14	5	First trial, struck left side platform, all others squarely. Sixty trials first day!
11/15/07	10	1	Went clear over.
	12	1	Struck and slid off east.
	10	5	First trial, overshot; second, scrambled, others perfect.
	11	5	Good; last trial, struck and slid off.
	12	5	First two, a little short, others perfect.
	13	5	As above. (Not so active. Muscular soreness from unusual exertion of yesterday?)
11/16/07	12	5	Three perfect, two scrambled.
	14	5	First trial, short and fell.
	15	5	First and second trials, a little short.
11/17/07	12	5	All good.
	14	5	First trial, a little short; second, scrambled.
	15	5	Same as above.
11/18/07	14	5	Four perfect.
	15	5	First and second a little short.
	16	5	Good.
	17	5	Perfect.
	18	5	First trial did not strike exactly in center.
	19	5	First trial, short and fell.
	20	5	A little short first trial, others perfect.
	21	5	As above.
	22	5	All perfect.
11/19/07	18	5	All good.
	20	5	Four trials perfect.
	22	5	Perfect.

Black-and-White Rat I.

	INCHES	TRIALS.	
8/26/07	8	8	Jumped almost at once but scrambled; second and third good; fourth, seventh and eighth, scrambled; all others good.
8/27/07	8	6	All good.
	9	5	Second, scrambled; all others good.
	10	10	First, scrambled; all others good.
	12	10	Second and ninth, scrambled; all others good.
	14	10	First and tenth, short and fell; third scrambled; others good.
8/28/07	8	2	Jumped entirely over both trials.
	12	10	Second and eighth scrambled; others good.
	14	6	First and third, scrambled; others good.
	10	10	Second and third, scrambled; others good.
	18	9	Third, fifth and sixth, scrambled; ninth, short and fell; others good. Was breathless and seemed tired.
8/29/07	12	2	Both jumps too long, went over platform.
	16	5	First, struck on north of platform and scrambled; distance good but direction faulty; third, scrambled; others good.
	18	10	First, too far north; second, third and sixth, scrambled slightly; ninth, toward north.
	20	10	Fifth, scrambled slightly; others good.
8/30/07	20	10	Sixth, scrambled slightly; ninth, short; tenth, good.
	22	10	First and third, short; seventh and ninth scrambled.
8/31/07	20	7	Second, scrambled; fifth and seventh, short and fell.
9/ 1/07	18	5	First and third, scrambled slightly.
	20	10	First, second, seventh and ninth, scrambled.
	22	10	First, scrambled; third, fell on south.

Black-and-White Rat II.

8/27/07	8	0	Would not jump.
	5	5	Stepped over easily.
	6	5	Hopped across.
	8	5	Hopped across.
	9	10	First, a little short; third, scrambled.
	10	10	First, scrambled.
	12	10	On seventh trial, fell off platform in preparing to jump. All other trials good.
	14	1	Short and fell. Tired.

	INCHES	TRIALS.	
8/28/07	10	0	Would not attempt it.
	6	5	*Very slow in starting.* All trials good.
	8	5	All good.
	10	5	All good.
	12	5	All good.
	14	4	First, scrambled; others good.
8/29/07	12	0	Would not attempt it. Waited 15 min.
	10	0	Would not attempt it. Waited 15 min.
	8	0	Would not attempt it. Waited 15 min.
	5	5	Seems much afraid and needs a great deal of coaxing.
	7	5	Better; all trials good.
	14	5	All good.
	16	5	All good.
	18	5	All good.
	20	2	All good.
8/30/07	16	10	*Very slow.* First trial, scrambled; tenth, short and fell.
8/31/07	16	0	Would not attempt to jump.
	14	5	Timid. First, too long and fell; others good.
	16	10	First, scrambled; fifth, fell off the south side of Platform II.
	18	5	First, second, third and fifth trials, scrambled.

Work with this rat was here suspended during an alteration of the apparatus. The remainder of the learning process was like that of the other normal rats at these distances, and is not quoted further.

c. On Blind Rats.

The experimenter attempted to train four blind rats. The animals were active, and one of them had had experience under experimental conditions. The method was the same as in the tests with the normal rats, though the procedure was *much slower.*

The rats were fed for several days upon Platform II, which was east of and 2 inches distant from Platform I. The animals were always placed on Platform I, facing the east, and after they had stepped across they were carefully lifted back and set down facing the east, upon Platform I. The normal

rats acquired their own orientation relative to Platform II; the blind animals always adjusted themselves for the jump in the position in which they had been set down upon the platform. With these blind rats it was necessary to make the increase by shorter gradations, one-fourth or one-half of an inch. Two of the rats would not attempt to cross a space wider than they could reach with their vibrissæ. The notes on the behavior of one of these is given below, beginning with the distance of four inches.[1] The notes taken on less distances contribute nothing. The number of trials is not always given, as they had not been counted at such short distances.

Blind Black-and-White Rat on Problem IV.

	INCHES	TRIALS.	
10/4/07	4	10	Stepped across to food platform, always from the southeast corner.
	4½		Stepped across many times.
	5		As above.
	5¼	10	Was obliged to spring a little; always from the southeast corner.
10/5/07	5		Would not try; failure. Was obliged to lessen distance.
	4½	4	Stepped across three times after much coaxing by holding food in front of him.
10/6/07	5		After thirty minutes he stepped across on his own initative from the south-east. Could not be coaxed across. Time, forty-five minutes.
10/7/07	4¼	10	Stepped across from southeast corner.
	5		Failure. Will only reach or spring as far as vibrissæ can touch.

The procedure as noted above was repeated for several days with little variation and no satisfactory results.[2]

A blind rat which also had had previous experience was

[1] This rat had successfully solved the previous problems.

[2] This rat would not allow his fore feet to leave the platform unless his vibrissæ reported contact with some object. When the platform was beyond the reach of his vibrissæ the experimenter touched their tips with a pencil, whereupon he put out his fore feet to step over. He never raised his hind feet until his fore feet had a firm footing, but he could always be induced to make an attempt by stimulating his vibrissæ. A deodorized glass rod was used instead of the pencil and it had the same effect, showing that it was contact alone, and not olfaction that tempted him to make the effort.

labored with for many days, with not so good results.[1] He would not step across when the platform was within reach of his nose. He was a slow rat at best and achieved no credit for himself in the previous experiments.

Blind Rats III and IV (white untrained females) achieved signal success in this test. Both learned eventually to jump distances of eleven inches, and Rat III successfully cleared fifteen inches. A portion of the notes on the behavior of this rat is given here as they are of particular interest.

Blind Rat III

	INCHES	TRIALS.	
11/19/00			Began the experimentation with the platforms two inches apart. Coaxed her across with a morsel of food. She used vibrissæ to locate the platform. Distance gradually lengthened to four inches. This was the daily program for ten days.
11/29/07	4½	10	Stepped across. An active rat.
	5	5	Hopped across. (Had never been able to get a blind rat to 'hop' before.)
	5½	5	Hopped across. Never turns around. (When returning blind rats to Platform I they were always placed with head toward food platform. They rarely altered this position.)
	6	5	Struck platform squarely.
11/30/07	4½		Would not hop across; obliged to reduce distance to four inches and increased one-half inch at a time. Would not cross after five inches.
12/1/07	4½		Good.
	5	5	Stepped across at five inches. Very slow.
	5½	5	Hopped after stretching across.
	6½	5	Sprang across.
	7½	5	Good.
	8½	5	First trial, heels on angle, others perfect.
	9½	5	Same procedure as above.
	10½	5	First trial, scrambled slightly.
	11½		Getting tired and slow. Scrambled in two trials and in fourth trial did not aim right; struck wall at northeast; fell hard but it did not frighten her. Commenced eating at once when placed on food platform.

[1] This rat was Male I whose records on Problems II and III were disregarded in the average of the groups.

	INCHES	TRIALS.	
12/3/07	5¾		Would not hop across and could not step across.
	5		Would not step across.
	4		Stepped across.
	5		As above.
	5¾	4	Coaxed across first trial. Hopped across in other trials.
	6¾	2	Went entirely over and struck wall.
	7½	4	Went over platform and fell first trial, second, the same, third, went to east side, and just saved herself from falling. Fourth trial, perfect.
	8½	5	All perfect. (For four days succeeding above there was the same procedure every day. At the beginning of each daily experiment, experimenter was obliged to reduce distance to four inches; the animals seemed to carry over nothing of advantage from one day's experience to the next. Each day learned anew to step across and later to jump to platform.)
12/7/07	7	2	Loitered about for a long time then jumped nearly across platform.
	9	2	First trial, perfect. Second, off at north.
	11	2	Perfect.
	13	4	First trial, scrambled up over edge. Second, fell.
	15	4	Did not strike the platform squarely. Scrambled each time on to the platform.
12/8/07	7	10	Jumped over platform to wall of canvass control cage. Does not jump to platform but jumps aimlessly. Eighth and ninth trials, struck wall at distance of twenty seven inches.
12/9/07	12		Jumped across to wall six times; distance twenty inches. Changed distance of platform but would not jump toward it. After dozens of trials the experimenter gave up in despair.

Rat IV had learned to strike the platform squarely at a distance of eleven inches. At this stage of her training she discovered that she could crawl down the standard. Sharp points were placed about the edge of the platform to prevent her descent, whereupon she jumped directly to the floor below. Further experimentation was futile.

d. On Anosmic Rats.

To determine accurately that vision and not olfaction furnished the sensory control of the adjustment, two anosmic rats were tested upon the apparatus.[1]

The method of training of this animal was the same as that with the blind rats—the distance being increased by half an inch at a time. The following are extracts from the notes taken on his behavior:

Anosmic Rat I on Problem IV.

	INCHES	
12/3/07	5	Steps across many times but awkward and afraid.
	5½	Has to be coaxed across; slow and evidently much disturbed by fear.
	5½	An entire failure after thirty minutes of coaxing.
12/13/07		After ten days of daily experimentation has made no progress. Was stiff with fright much of the time when urged to take a distance greater than he could step across. For several days he has been gnawing fiercely at the sides of Platform I and has rounded off the edges and corners.
12/14/07		Failure!

A second anosmic rat was procured for the test. He was hurried through the series with a fewer number of trials at each distance because of the experimenter's apprehension concerning the length of his tenure of life. He was in excellent physical condition but had he died there would have been no possibility of procuring another anosmic rat in time for the experiment. On the first day he succeeded in convincing the experimenter that the olfactory stimulus was not the essential factor in the jumping reaction. The notes quoted below give the details of his record.

[1] The first animal was the one which had formed the associations involved in Problems I, II and III, though his time records in the last two problems were practically of no value because of the time he wasted in gnawing the apparatus.

Anosmic Rat II on Problem IV.

	INCHES	TRIALS.	
12/6/07	5½	1	First time upon platform. Stepped across immediately.
	6	1	Jumped readily to Platform II.
	8	2	Perfect. No hesitation.
	9	3	First trial, scrambled; others perfect.
	10	3	Exact repetition of previous trial.
	12	3	Same as above.
	13	3	Scrambled, tired. (All of the above trials within ten minutes.)
12/7/07	7	2	Jumped across.
	9	2	Perfect.
	11	4	First trial, scrambled; others perfect.
	13	3	Third trial, scrambled a little.
	15	3	First trial, scrambled; others perfect. Very active.
12/9/07	7	2	Did not jump readily at first, finally coaxed across. Struck squarely.
	9	2	Perfect.
	11	3	First trial, scrambled; others good.
	13	3	Perfect.
	15		Short, and fell twice; afraid, put him up.
12/12/07	6	1	Would not jump at first.
	8	1	Same as above.
	14	4	First and second trials, scrambled; other trials perfect.
	15	5	As above. (Is lame in left hind leg.)
12/15/07	16	5	Slow. First trial, struck on south side. Second, same but nearer center.
	18	5	First and third trials, scrambled slightly.
	20	3	Second trial, struck platform, but fell off.
	22	7	Fourth trial, scrambled; sixth, little short and fell. Tired.

The behavior of this rat in the above test was in every respect like that of the normal animals. He had had previous experience on Problem I, and was apparently undisturbed emotionally by the conditions of the experiment. He learned to jump his maximum distance in a shorter time than did any other white rat, though to what extent his facility was due to fearlessness and to the fact that the experimenter lost no time in lengthening his distances cannot be estimated.

ii. Summary.

1. Five normal white rats, the three normal black-and-white rats, and one anosmic animal were able to learn to jump successfully a distance of at least 22 inches. These adjustments were acquired with comparative ease. One other normal white rat learned to jump as long a distance as 22 inches with difficulty, and another did not learn to jump more than 15 inches. No normal rat failed to learn to jump. Two of the blind rats (III and IV) achieved success in this test. Both learned to jump a distance of 11 inches. One (Rat III) learned to jump a distance of 15 inches. Here the coördination broke down apparently on account of the fact that a large percentage of her jumps were inaccurate; she had to scramble onto the platform much of the time, and she often failed utterly to strike it and consequently fell. Rat IV learned to jump a distance of 11 inches, but the coördination broke down upon her discovery that she could crawl down the standard.

2. One anosmic and two blind rats were utter failures. Two were willing to step across to the second platform, but they were either unable, or else refused, to jump. The failure of the anosmic rat was probably due to the fright occasioned by the unusualness of the conditions of the experiment and not to any lack of proper sensory control. Under any other circumstances he ran about naturally in search of food. The blind animals did not seem to be emotionally disturbed, and hence their failure was probably referable to a lack of adequate stimulus.

3. *Effect of Changing Direction in which Jump Must be Taken.*

In order to determine more accurately the sensory factors involved in the coördinaton it was decided to change the position of the apparatus and thereby the direction in which the animal has to jump. It would seem that if the rats can accommodate *at once* to changes in the direction of Platform II, some distance receptor must be operative. Such a test might also show the possible presence of some 'directional' factor which

is not visual in character. Three white rats had been trained to jump distances gradually increasing from 6 to 30 inches. These longer distances, as has been noted, were too great to permit of accurate adjustment on the part of the rat, and they demanded an unnecessary expenditure of energy. Accordingly, a record of 80 per cent of perfect coördinations at 22 inches was chosen as a standard of efficiency to be attained before the animals should be tested with the apparatus turned in another direction. Three white rats had reached this degree of capability.

The apparatus was then so adjusted that the rat must jump 22 inches to the south for food. To the surprise of the observers, two of the rats continued to jump toward the east for twenty successive trials each. The third rat jumped twice toward the south, though he did not jump far enough to land on the platform; at the third trial he settled down comfortably on the starting platform and refused to jump.

Acting on the possibility that the two rats were jumping toward their cages—which were to the east—or reacting to other features in the environment of a visual or olfactory character, the conditions of the experiment were radically changed.

A cabinet 4 feet by 4 feet, by 6 feet was built. The framework was of 2 by 4 inch timber, the sides and top of white canvas. The cabinet was illuminated by a 32 c.p. electric light fastened to the center of the top of the cabinet. The visual and olfactory conditions of the environment were thus rendered subject to control. At this time the apparatus itself was improved. The connecting rod was made of 1 inch pipe, clamped in iron end supports. The uprights supporting the platforms were of ½ inch steel, clamped at right angles to the base. One of the uprights consisted of two 18 inch steel bars clamped together so that the height of platform it bore might be varied from 18 to 30 inches. The apparatus in this form was much more easily adjusted to horizontal changes in distance. It also possessed the added advantage of offering any possible adjustment in height.

While working with the wooden platform the feet of the

animal became sore. In making such leaps as are necessary in these tests—covering sometimes a distance of 24 inches—the rat lands heavily upon the forefeet. This might have been the cause of the soreness. The platforms were later covered with cork matting, and this in turn with soft leather. The whole was then painted light gray. Though the paint added somewhat to the resistance of the surface the rats had little difficulty thereafter with soreness of the feet.

After the cabinet had been constructed, the rats which had learned to jump on the old apparatus were tested in the new one. There had been an interval of three weeks since their last trials and several days' training was necessary to bring them up to their former standard of accomplishment. While training the rats the experimenter remained within the cabinet to catch them when they fell and to feed them immediately after they reached the platform. After the habit had been reëstablished and it was desired to test the animal with the apparatus in a new position, the rat was observed from without through a slit in the canvas. The position of the observer outside the cage was also changed in every test, in order that the rat might not associate the sound of the experimenter's movements with the direction in which the jump must be taken.

The possibility of an olfactory stimulus was here minimized by allowing no food in the cabinet. The rat was fed from the experimenter's hand after the jump, and Platform II was kept clean, and newly covered, top and sides, with black-and-white checkered cloth—to add greater character to the visual stimulus.

Each day before the apparatus was turned the rat was given five or more tests in jumping toward the east which during the previous training had been the constant direction. If 80 per cent of the trials were perfect, the cabinet and apparatus were rotated. This change necessitated jumping to the south, the north, or the west, as the alteration might demand, in order to reach Platform II. Care was taken to place the rat on Platform I in different positions during the various trials, so that the initial position would be no cue to the essential orientation.

i. Statement of Results.

a. On Normal White Rats.

The records of the normal white rats in this test are given below.

White Female I.

	POSITION OF PLATFORM II.	
12/9/07	East 22 in.	Ten trials, 80 per cent perfect.
	South.	Perfect.
	West.	Refused to jump.
	North.	Refused to jump.
	West.	Jumped south.
	East.	Refused to jump.
12/10/07	East.	Eight trials, all good.
	North.	Went entirely over platform to north, and struck canvas.
	West.	Refused to jump.
	South.	Fell off platform in preparing to jump toward south, and was frightened. No other tests today.
12/11/07	East.	Five trials, perfect.
	West.	Perfect.
	South.	Jumped east.
	North.	Perfect.
	West.	Jumped south.
12/12/07	North.[1]	Jumped east.
	West.	Jumped south.
12/13/07	South.	Jumped east.
12/14/07	South.	Jumped east.
	North.	Slow and confused. Will not jump.
12/15/07	West.	Refused to jump, apparently much confused.
12/16/07	East.	Same as above.

[1] Platform II was not placed at the east for the first trial, as the animal exhibited a tendency to jump east habitually, and it was feared that this position might unduly emphasize the tendency.

White Male II.

	POSITION OF PLATFORM II.	
12/6/07	East 24 in.	Ten trials, 80 per cent perfect.
	South, 22 in.	One trial, immediate and perfect accommodation.
	West, 24 in.	One trial, perfect, jumped at once.
	North, 24 in.	Direction perfect, but jumped too short.
	East, 24 in.	One trial, perfect.
		Apparatus turned but not cabinet.
	North, 24 in.	One trial, perfect.
	North, 24 in.	One trial, perfect.
	East, 24 in.	One trial, went slightly to right of platform, grazing the side.
	West, 24 in.	One trial, perfect.
12/7/07	East, 24 in.	Ten trials, and but 30 per cent perfect. Jumped down toward bottom of apparatus. Did not try to jump to platform.

White Male III.

12/6/07	East, 24 in.	Five trials, scrambled slightly each time. Animal is ill and weak.
	North, 24 in.	One trial, right direction but short.
	South, 24 in.	One trial, same as above. Did not work again and died soon after.

Two of the three rats jumped to the platform in the new position at every test on the first trial. The third rat, Female I, jumped to the platform which was toward the south on the first trial, but on the second, third, and fifth trials she refused to jump. On the fourth she jumped south again when she should have jumped east. On the first trial for the second day with platform north she jumped to it at once, then refused to jump the next time. On the first trial on the third day the adjustments were perfect, though on two of the later trials she jumped in the wrong direction. On the fourth, fifth and sixth days she made no perfect coördinations, either jumping to the east, with one exception, or refusing to jump at all. The tests had to be discontinued because of her disinclination to leave Platform I. She would jump toward the east with

the platform in that direction but not otherwise. In the case of Rat II, also, there was a tendency for the coördination to break down under the changed conditions, as this rat took to jumping toward the base of the opposite standard, and could not thereafter be induced to jump to the platform. This series was necessarily abbreviated on that account.

b. On Normal Black-and-White Rats.

Three black-and-white rats were given the same test. They had attained the necessary standard of efficiency, i. e., 80 per cent of perfect coördinations at 22 inches. The following are from the notes taken on this series.

Black-and-White Female I.

	POSITION OF PLATFORM II.	
10/29/07	East, 22 in.	Five trials; 100 per cent perfect.
	South.	One trial, perfect.
	West.	Jumped southeast five times in succession apparently at a shadow caused by the joining of the canvas strips.
10/30/07	East.	Six trials, 80 per cent perfect. Shows tendency to jump toward northeast.
	South.	Two trials, first, slightly to east of south. Second, perfect.
	West.	Two trials, first; slightly to south of west; second perfect.
	South.	One trial, jumped to wall on south.
	East.	Two trials, first, jumped to south; second to east.
	West.	Two trials, first, southwest; second, perfect.
	North.	Refused to jump.
11/1/07	East.	One trial, perfect.
	North.	Jumped northeast to canvas.
		Same relative direction.
	West.	Jumped southeast.
	North.	Jumped northeast to canvas.
11/5/07	South.	Jumped northeast to canvas. Jumped to wall repeatedly but not to platform. Tests discontinued.

Black-and-White Female II.

	POSITION OF PLATFORM II.	
11/30/07	East.	Five trials, 60 per cent perfect, others good.
	South.	One trial, perfect.
	North.	One trial, perfect.
	South.	One trial, perfect.
10/31/07	East.	One trial, perfect.
	South.	One trial, perfect.
	West.	One trial, perfect.
	North.	One trial, perfect.
	West.	One trial, perfect.
	North.	One trial, perfect.
11/1/07	East.	One trial, perfect.
	West.	One trial, perfect.
	South.	One trial, perfect.
	North.	One trial, perfect.
		TURNED APPARATUS BUT NOT CABINET.
11/2/07	South.	One trial, direction perfect but distance short.
	West.	One trial, rat confused. Put back.
11/3/07	East.	One trial, direction correct, distance short.
	North.	One trial, perfect.
	West.	One trial, perfect.
	South.	One trial, perfect.

Black-and-White Female III.

11/19/07	East, 22 in.	Ten trials, 80 per cent perfect.
	South.	One trial, good.
	West.	One trial, good.
	North.	One trial, good.
	East.	Eight trials, 75 per cent perfect.
	North.	One trial, perfect.
	South.	One trial, perfect.
	West.	One trial, jumped to floor.
11/21/07		Very active rat; gets innervation before muscular accommodation, consequently makes random leaps.
11/24/07		Will jump only to floor. Tried several devices to prevent this, but none successful. Series discontinued.

The black-and-white rats, like the white ones, reached a point in the tests where the accommodation to the distance and the direction broke down completely, though it did not break

down so soon. These rats had not been at work at the test as long as the white animals which had been trained upon the old apparatus and retrained upon the new.

c. On Anosmic Rat.

The anosmic rat had just reached the necessary maximum of 22 inches before the test with apparatus rotated could be made. He had been given two trials with the apparatus changed. Through some mishap on the part of the laboratory attendant the rat gained his liberty, and was not seen thereafter. His records for the two trials follow:

Record of Anosmic Rat: Position of Apparatus Variable.

	POSITION OF PLATFORM II.	TRIALS.	
12/15/07	East	7	Fourth trial, scrambled; sixth, short and fell. Seems tired.
	South.	1	Slow, but accurate.
	West.	1	Good. Very slow.

ii. Summary.

1. Four of the six rats were able to direct their jumps equally well, regardless of the direction in which the jump must be taken. The other two animals were able to accomplish this in about 50 per cent of their trials.

2. These two other rats were by no means failures on the problem. One of them, White Female I, jumped to Platform II which was south at the first trial. She had always previously jumped to the east. After this trial she often refused to make the effort. Of the twelve trials in which she made an effort, she was five times successful in the direction of her jump, and failed seven times. Of these seven failures, four were jumps to the east and three to the south.

The remaining rat, Black-and-White Female I, did not attempt to jump toward Platform II when it was turned to the south, but jumped five times in succession to a point in

the wall of the cabinet where one width of canvas overlapped another, and wriggled through, emerging on the outside of the cabinet. On the following day she jumped in the direction of Platform II, five trials, though she did not always strike it squarely on the first trial, then missed by jumping south when she should have jumped east. Soon after she failed to make any attempt to jump to Platform II, but jumped to the walls instead.

4. *Effect of Altering Distances Between Platforms.*

a. Effect of Altering Horizontal Distance.

During the training period it became evident that the rats were unable to accommodate with any degree of ease to a distance which was shorter than the one for which they had established a habit. It will be remembered that the rats had to start any given day's work with a jump which was slightly shorter than the maximum jump which they had been able to attain the day before. Under such conditions the animals would often over-innervate for the first few trials and jump entirely over Platform II.

A series of tests was undertaken to determine (1) the number of trials necessary for and (2) the sensory factors involved in a readjustment to shortened distances. The experiments are not so numerous as had been planned by reason of the fact that the coördination had broken down in many of the animals. The preceding section shows that changing the direction in which the jump must be taken tended to disintegrate the coördination with all the animals but one. If this had been predictable, the present experiments would have preceded those of the last section.

The tests here reported upon were made in the cabinet under conditions closely similar to those reported in the last section. The food, however, consisting of sunflower seed, was placed in a small receptacle which hung from the far edge of Platform II. It afforded no visual and probably little olfactory stimulation.

Before decreasing the distance between the platforms the now thoroughly experienced animals were allowed to establish a habit for the distance of twenty-two inches. The distance was then shortened and the effort of the animal to accommodate to it was recorded. The notes below show the changes made and the essential features of the animal's behavior.

i. Statement of Results.

α. On Normal White and on Normal Black-and-White Rats.

The results on the white and on the black-and-white rats are given together, since the numbers are too small to justify a separation. Only three animals could be used for the purposes of the test. The notes on the behavior of Female III are given below.

White Female III.

	INCHES.	TRIALS.	
12/31/07	22	5	First and second, to left of center of platform; third, fourth and fifth, good.
1/1/08	16	5	First, long, went over platform; second, struck but slid off far edge; third and fourth, good; fifth, perfect, struck squarely.
	8	8	First, entirely over and struck opposite wall of cabinet; second, third and fourth, shorter but entirely over; fifth, like first; sixth, seventh and eighth, entirely over.
1/2/08	22	5	First short, about one-half of distance to platform; other four trials good.
	8	5	First, second, third and fourth, long; fifth, struck platform in passing but slid off.
1/3/08	22	5	First trial, short; second, landed on the right side of the platform; fourth, scrambled; fifth, good.
	16	5	First, struck platform in passing over; second, struck squarely; third and fourth, scrambled; fifth, good.
	8	1	Went entirely over at first trial and refused to jump again.
1/4/08	22	0	Failure—refused to jump.

White Male I.

	INCHES.	TRIALS.	
8/24/07	22	4	All perfect.
	12	10	First trial, second and third, entirely over; fourth, his hind feet and tail grazed platform as he went over; fifth and sixth, over, but shorter and struck platform with his tail; seventh and eighth, grazed, platform with all fours as he went over; ninth, struck platform on far side and slipped off; tenth, landed on further side of platform but stayed on.
8/25/07	22	0	Rat refused to jump; was evidently not well. The animal had a sore foot and the tests were discontinued. It died soon after.

Black-and-White Female III was experimented with and her records follow.

Black-and-White Female III.

	INCHES.	TRIALS.	
10/14/07	22	5	First trial, scrambled; other four trials perfect.
	16	5	Jumped entirely over platform at every trial.
10/15/07	22	0	Refused to jump.
	16	0	Refused to jump.
	8	22	Went over platform at every trial; seemed to be jumping about 22 inches.
11/4/07	22	5	All good.
	8	10	All much too long.
	16	10	First trial, shorter than 22 inches but entirely over platform; second, shorter than first; third, feet grazed plane as she went over; fourth, same; fifth, struck but slid off; sixth, good; seventh and eighth, like fifth; ninth and tenth, good.

b. Effect of Altering both Horizontal and Vertical Distances.

Up to this time the platforms had been at the same height, so that the main direction of the necessary jump was horizontal. The apparatus was now adjusted so that Platform II was 6 inches higher than, and at a distance of 16 inches from Platform II. Several rats were tested under this condition, but

the upward spring seemed almost impossible of acquisition and no rat was successful. The attempt to jump upward was unmistakably made, with the result that the animal sometimes struck with considerable force against the standard or the under side of the platform, or else landed on the wall opposite or upon the floor. No long continued effort was made to train the few remaining jumpers lest the repeated errors should render them unfit for further experimentation.

The apparatus was then re-adjusted so that Platform II was 10 inches below the level of and 16 inches distant horizontally from Platform I.

i. Statement of Results.

α. On Normal White, and on Normal Black-and-White Rats.

The notes on the behavior of the two remaining animals follow.

White Female III.

	INCHES.	TRIALS.	
1/6/08	22	5	All good.
	16 Horizontal 10 Vertical	5	Was slow in preparing to jump; seemed ready to spring several times before she finally essayed it. Looked downward toward the platform. First, landed on left margin of platform; second, third, fourth and fifth, good.
1/7/08	16 H. 10 V.	5	Same slow and elaborate preparations as yesterday. First and second, perfect; third, scrambled slightly; fourth and fifth, perfect.
	8 H. 10 V.	5	Slow in starting. Jumped downward but considerably over the platform. Did not seem at any trial to shorten her jumps from those of yesterday. All trials a failure.
1/8/08	8 H. 10 V.	5	Behavior as before, only slower. No successes.
1/9/08	8 H. 10 V.	2	After long intervals she jumped twice with results as above; then seemingly discouraged she settled down for an hour and refused to make any efforts.
1/10/08	8 H. 10 V.	0	Would make no effort.

Black-and-White Female II.

	INCHES.	TRIALS.	
1/5/07	22 H.	5	All trials perfect.
	22 H. 10 V.	5	Jumped down and struck platform squarely, but angle was so great that she slipped off; second, struck squarely and slid but did not fall off; third, fourth and fifth, perfect and with less force.
	16 H. 10 V.	10	First, entirely over; second, struck platform with hind legs and tail as she passed; third, shorter but still over; fourth, fifth and sixth, landed but slid off by reason of momentum; seventh, eighth, ninth and tenth, struck squarely on platform and did not slide.
1/6/07	16 H. 10 V.	6	First, struck platform with hind feet only; others good.
	8 H. 10 V.	10	First and second, over; third, over but struck in passing; fourth, shorter; other six trials entirely over.
1/7/07	8 H. 10 V.	20	No nearer coördination than before.
1/8/07	8 H. 10 V.	8	As yesterday; all trials were failures. The platform was then moved out to the point which would intersect her leap. The distance proved to be 15 inches.
	15 H. 10 V.	6	First, struck platform with tail; second, struck platform on right side and fell off; third, struck on right side but stayed on; fourth, jump a little long but stayed on platform; fifth, struck it and fell off; sixth, good.

ii. Summary.

1. No rat was able to make the adjustment when the distance was changed from 22 inches to 8 inches in a reasonable number of trials. One rat failed after seventy trials. All animals were able to adjust without *great difficulty* to the change from 22 to 16 inches apparently by means of a trial and error method. An average of about one trial was necessary in order to effect this readjustment. When the dis-

tance was shortened the animals always jumped too far on the first trials.

2. In the few cases where the distance was suddenly lengthened the jump was usually too short on the first trials. It was impossible to compare the ease of the readjustment to the lengthened distances, with that for the shortened distances, by reason of the fact that the animals were taught to jump long distances by gradually increasing the distance between the platforms. The adjustment to an increased distance was thus more habitual than that to a shortened distance.

3. The animals were able to adjust successfully at once for the lowered position at 16 inches. They could adjust for a lowered and shortened distance more easily than for merely the shortened distance. They could not, however, adjust to the lowered and shortened position at 8 inches. It was evident that they were making the effort but they invariably jumped out too far.

5. CONCLUSIONS.

The purpose of the foregoing tests was to estimate the importance of vision in the coördination required in jumping. Three aspects of the coördination as a whole were considered: *a* Learning to jump a given distance when the direction of the jump was constant; *b* the effect, after the jump under constant conditions had become automatized, of changing the distance of the jump, the direction remaining constant as before; and *c* the effect of changing the distance and the direction of the jump in either the horizontal or vertical planes, or in both. The data gathered from the various experiments seem to justify the following general conclusions, stated in the order of the problems as indicated above.

a. Learning to Jump—Direction Constant.

The results indicate that the loss of vision in some way interferes with learning to jump long distances and greatly decreases the ease and rapidity in the acquisition of the coördination for short distances. In the case of the two blind

individuals which failed, it seemed that some element was lacking which was essential to the initiation of the act. The fact that two blind rats learned to jump even the shorter distances, and that the normal animals had to accommodate by a trial and error method to sudden increases and decreases in the distance between platforms, indicates that up to a certain point, other than visual factors are concerned in these adaptations to a distant stimulus. The blind animals, unlike the normal animals, did not move about when placed facing the east on Platform I: they were given their orientation and retained it. The normal animals moved about on the platform so continuously that the experimenter made no effort to put them down in a relatively constant position. The fact that their orientation was given to the blind rats was probably the reason of their success. An attempt was to have been made to test this factor by changing the initial position, but the coördination disintegrated before the test could be made. Certainly the experiments on the process of learning to jump are not decisive in indicating what rôle vision plays in this coördination.

It has been shown that the tactual, kinæsthetic and olfactory senses are able to mediate accurate adjustments to short distances even in the absence of visual impulses. The separate rôle played by each of these senses in the case of the blind animals has not been determined. Judging from the tests upon the anosmic animals it would appear that olfactory stimuli can be dispensed with both during the acquisition of the habit and at all later times. Touch, as a partially controlling factor, does, however, enter into the early adjustments of the blind animals, since they will more readily form the habit of jumping if the snout or vibrissæ are stimulated by the platform to which the animal has to jump. This latter statement applies in some degree at least even to the animals possessing vision. Once the habit is formed, however, the initial tactual impulses can be dispensed with.

In regard to the function of kinæsthetic impulses in the case of the blind animals, it seems safe to affirm that they soon come to usurp whatever function tactual impulses from the snout and vibrissæ exert in the learning process. They soon

become the only indispensable means of control in the blind animal for such short jumps as they were able to accomplish.[1]

b. Effect of Lengthening or Shortening the Jump, Direction Constant.

From the experiments on p. 93 it follows that the change in visual impulses conditioned by lengthening or shortening the distance between the platforms is not adequate to effect the change in innervation necessary for a successful coördination. Lengthening or shortening the distance between the platforms may bring about a change in accommodation and in convergence (kinæsthetic factors) and certainly occasions a change in the intensity of the visual impulses and the size of the area of the retinal elements which receive the stimulation (change in visual impulse proper). In the case of these types of animals, monkey, cat, etc., where adjustments under similar conditions are accurate, the above noted changes in the sensory complex in all probability are sufficient to bring about the proper modification in the motor discharge. In the case of the rat, however, these delicate changes in sensory stimulation are inadequate to modify the habitual motor response. The rat apparently, in order to accommodate to the changes in distance, must make trial movements, that is, *must establish a habit of jumping a given distance.* Any change in the distance calls for learning factors similar to those already discussed on p. 72. It is evident that by means of these trial jumps the animal is bringing *into play the large muscles of the body* (as contrasted with the eye muscles and the ciliary muscle) *and is thereby gaining a control over the motor area which it is perhaps impossible to obtain by the visual changes and the changes involved in accommodation and in convergence.* These facts in themselves are suggestive of the relatively secondary importance of vision in the life of this animal.

It is thus seen that the attempt to eliminate the function of kinæsthetic impulses by irregularly changing the distance has

[1] The term kinaesthetic as here employed necessarily includes whatever impulses come from the skin of the feet. These impulses are presumably fused with those from the muscles.

not been successful in isolating the rôle of vision, by reason of the fact that when the distance is altered the habit breaks down and readjustment must take place. Had the animals been able to accommodate to the changed conditions without trial movements, the conclusion that the visual complex (visual impulse, accommodation and convergence) was the essential sensory factor involved in this coördination would be justified. But since trial movements are necessary, the problem remains as to whether kinæsthetic impulses alone are responsible for it.

c. Effect of Changing Direction of Jump.

The experiments summarized on p. 92 and p. 98 were much more successful in giving evidence of the function of a distance receptor. Since the possibility of the use of olfaction as a sensory control had been practically eliminated by previous experiment by precautionary methods above described, and since audition could not have furnished such guidance, it is evident that vision or some other undetermined receptor, functioned here in such a way as successfully to control the adjustment to a distant stimulus. Assuming for argument that vision is the effective source of control, it may be maintained that the visual impulse seems to afford evidence concerning the direction of the stimulus but is apparently not alone capable of controlling the amount of innervation necessary to make the requisite adjustments. In other words, visual impulses in such a form as may be designated white light vision are operative[1] and afford a basis for controlling the direction of the adjustments, but do not operate so as to furnish information concerning the third dimension.

Four rats of the six were able to adjust accurately and immediately to any direction of Platform II, (p. 92). A fifth was successful in five out of twelve trials including the *first*. The sixth rat, (when she was not jumping through a slit in the canvas before the cabinet was lined with other material) made the adjustment correctly in five trials out of six.

[1]Watson (*Animal Education*, p. 85) remarks "other things being equal, rats show a decided preference for well-lighted rather than dark places."

In the experiment in which both the distance and direction were changed, the two rats tested made the successful coördination. In this test, it will be recalled, the rat was obliged to jump downward and outward to reach Platform II, a horizontal distance of 16 inches from, and a vertical distance of 10 inches below Platform I. The downward jump had not hitherto been required in the experiment, and the animals accommodated themselves to the change immediately. Possibly this immediate accommodation was due to the fact that Platform II, being 10 inches below the level of Platform I, afforded a visual stimulus area about four times larger than when in the horizontal plane of Platform I. The stimulus was thereby much more effective. This fact of instant adjustment to a directional change, and a trial and error method of adjustment to a merely distance change, is the basis for the assumption that vision (or some other unknown distance receptor) affords information as to the direction but not as to the distance, of the stimulus. The observation that while the animals could jump downward to Platform II at 16 inches distant horizontally from the support of Platform I and 10 inches below it, but not at 8 inches horizontal distance [and 10 inches below] confirms an earlier statement that vision is in many instances overruled by the habitual innervation tendency.

The possibility of a directional factor seems to receive some confirmation in the results of the test. Of the eight cases of miscoördination (not due to jumping toward the canvas) four were jumps toward the east, the direction in which the jump was learned, and four were toward the south, the direction of the first jump after the change. What the nature of such a factor may be the present test made no attempt to investigate. Whether it was this factor which led to the breakdown of the coördination in the case of every rat but one is a question which only further experimentation can solve.

PART SECOND

A. EFFECT OF TRAINING UPON THE RATS.

I. Experimental Results.

1. Comparison of Records of Trained and of Untrained Rats.

a. Normal White Rats on Problem I.

While training two female white rats upon Problem I for a purpose other than that of these tests, it was found that their time-records were lower than normal. They had previously learned the Hampton Court maze. Thinking that this lower time record might be the result of tuition, the records of these rats were preserved in order that they might be compared with those of *normal untrained* animals upon the same problem. In Table XII is given the averages of the trained and of the untrained groups; and on Plate V is shown the averages of both groups.

TABLE XII.

Showing (1) *the average time-record of* 8 *untrained normal white rats,* (2) *the average time-record of two trained normal white rats, and* (3) *the time-records of a trained blind anosmic rat upon Problem I.*

NO. OF TRIALS.	1.	2.	3.
	min.	*min.*	*min.*
1	7.04	5.69	.55
2	1.69	.23	.18
3	.48	.09	.30
4	.80	.43	.12
5	.35	.10	.07
6	.30	.05	.11
7	.25	.09	.10
8	.23	.11	.06
9	.27	.05	.30
10	.18	.10	.12
11	.16	.05	.05
12	.13	.14	.08

TABLE XII.—Continued.

NO. OF TRIALS.	1.	2.	3.
13	.15	.05	.17
14	.09	.05	.05
15	.11	.05	.22
16	.14	.14	.10
17	.18	.08	.12
18	.13	.04	.07
19	.19	.06	.22
20	.09	.04	.05
21	.17	.06	.10
22	.12	.06	.05
23	.11	.07	.10
24	.23	.37	.11
25	.14	.07	.05
26	.10	.12	.11
27	.08	.15	.04
28	.12	.06	.05
29	.15	.10	.04
30	.07	.09	.08
31	.07	.06	.06
32	.06	.05	.05
33	.12	.07	.06
34	.17	.05	.07
35	.09	.15	.07
36	.19	.05	.12
37	.14	.04	.07
38	.09	.05	.10
39	.09	.05	.10
40	.09	.03	.07
41	.24	.04	.08
42	.15	.06	.09
43	.12	.05	.06
44	.11	.21	.14
45	.10	04	.05
46	.06	.04	.05
47	.06	.05	.07
48	.06	.12	.06
49	.06	.05	.05
50	.23	.04	.07

The comparison shows that the averages of these trained normal animals are far below those of the untrained normal white rats. The average of their records is—in the main—below the minimal time-records of the normal untrained group.

PLATE V

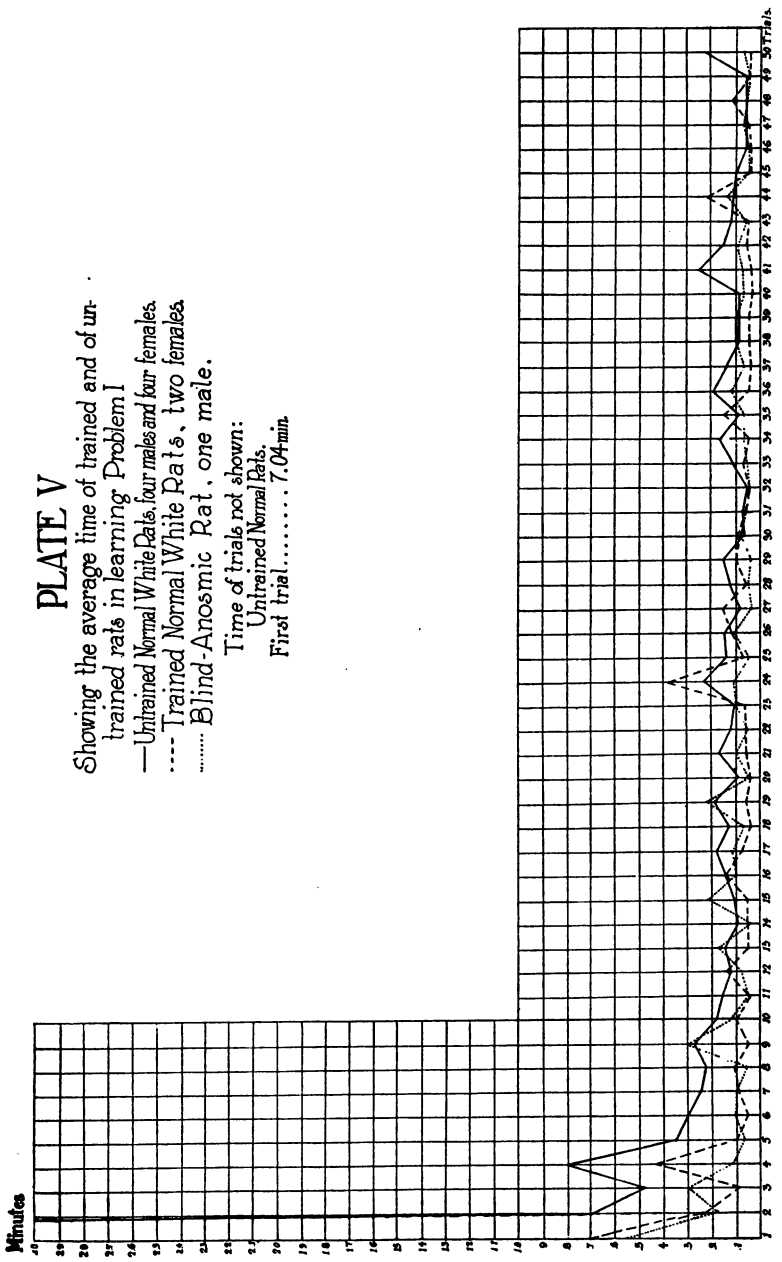
Showing the average time of trained and of untrained rats in learning Problem I

—Untrained Normal White Rats, four males and four females.

---- Trained Normal White Rats, two females.

..... Blind-Anosmic Rat, one male.

Time of trials not shown:
Untrained Normal Rats.
First trial..... 7.04 min.



The average of the lowest two records of the normal group is considerably above that of the average of these two experienced rats. No conclusions are justifiable upon the results of this comparison, since the two animals *might* have been extreme variations. The records are, therefore, tentatively put forth in connection with those of other trained and untrained groups.

The records of these two trained females averaged by tens in a series are given below. They may be compared with other records of the same kind on p. 21.

The Average Time-Records of the two Females for Entire Series.

	min.		*min.*
Female I	.19	Female II	.20

Average Time-Records by Groups of Ten.

Trials.	*Female I.* *min.*	*Female II.* *min.*
1–10	.68	.71
11–20	.08	.06
21–30	.06	.10
31–40	.07	.05
41–50	.07	.07

Female I made a total of five errors, and Female II a total of six errors in the series.

b. Blind Anosmic Rat on Problem I.

The time-records of the blind anosmic rat upon this problem are given in Table XII. He had been trained in the maze during a long series of tests. This rat was undoubtedly a very robust animal. His records on Problem I are much below those of the untrained normal rats, the blind rats, or the anosmic rats with vision. He became very active when put into the control cage and attacked the problem at once.

The Average Time-Record for Entire Series (50 Trials).

Blind Anosmic Rat ..... .10 min.

Average Time-Records by Groups of Ten.

	min.		*min.*
1–10	.19	31–40	.08
11–20	.11	41–50	.07
21–30	.07		

This record may be compared with those of the other rats which are given in the section on Problem I (p. 21).

Each of the two curves, representing the averages of rats which had had previous training, are lower than any one of those representing the averages of untrained white rats.[1]

c. Normal White Rats on Problem III.

Four untrained normal white rats were set to work upon the problem. Three of the animals were males about 150 days of age, and one female 128 days of age. The method of conducting the experiment was the same as in the earlier test. The rats were tame and in good physical condition.

Their method of solving the problem was the same as that of the trained animals, except that the untrained rats consumed much more time in achieving their first successes. The minimal time record for the first trial was more than 29 minutes. The rats were energetic and industrious, but they spent a great deal of time examining the control cage, though, like the trained animals they had been fed for three days in the cage to accustom them to the environment. Their average was not reduced to one minute until the fifth trial. The averages of the trained rats on the other hand did not go above one minute after the first trial. The averages of the untrained rats were reduced to .10 min. at the twenty-first trial though they were higher thereafter; while the averages of the trained animals dropped below .10 min. on the seventh trial and were later no higher.

Table XIII and Plate VI show the averages of these trained and untrained animals.

The curves show very plainly the great difference in time-records of the early successes and also show the fact that even from the thirty-fifth to the fortieth trial the records of the untrained rats were not so low nor so uniform as those of the trained rats from the tenth to the fifteenth trial.

[1] In view of a possible difference in the function of vision between white rats and those having pigmented eyes, it is no more than fair to limit the comparison here to records of albino rats.

TABLE XIII.

Showing the average time-records of trained and of untrained normal white rats on Problem III. The first column of averages represents the group of seven trained rats; the second, the third, and the fourth columns, the average, the minimum, and the maximum time-records of the untrained rats.

NO. OF TRIAL.	AVERAGE.	AVERAGE.	MINIMUM.	MAXIMUM.
	min.	*min.*	*min.*	*min.*
1	5.72	40.14	29.15	54.38
2	.32	5.97	2.76	13.17
3	.33	.80	1.28	11.27
4	.17	7.77	.62	13.87
5	.29	.92	.45	2.17
6	.22	.91	.55	1.65
7	.09	.99	.25	2.58
8	.09	.37	.07	.98
9	.06	.43	.22	.75
10	.06	.28	.20	.43
11	.07	.24	.12	.37
12	.05	.13	.08	.25
13	.05	.22	.07	.35
14	.05	.23	.14	.30
15	.05	.23	.13	.35
16		.15	.10	.25
17		.21	.10	.45
18		.19	.12	.27
19		.22	.08	.43
20		.11	.05	.18
21		.09	.03	.22
22		.08	.03	.18
23		.08	.03	.17
24		.10	.03	.28
25		.17	.02	.58
26		.08	.03	.20
27		.07	.04	.10
28		.06	.03	.10
29		.06	.03	.15
30		.04	.03	.05

d. Normal Black-and-White Rats on Problem III.

Table XIV and Plate VII show the averages of the trained and untrained groups of black-and-white rats on this problem. The difference in the two curves is rather startling and calls for some descriptive comment.

PLATE VI

Showing the average time of trained and of untrained normal white rats in learning Problem III.

—Trained Rats, four males and three females
---Untrained Rats, three males and one female.

Time of trials not shown:

	Trained Rats.	Untrained Rats.
First trial	5.72 min.	40.14 min.
Second trial		5.97 min.
Fourth trial		7.77 min.

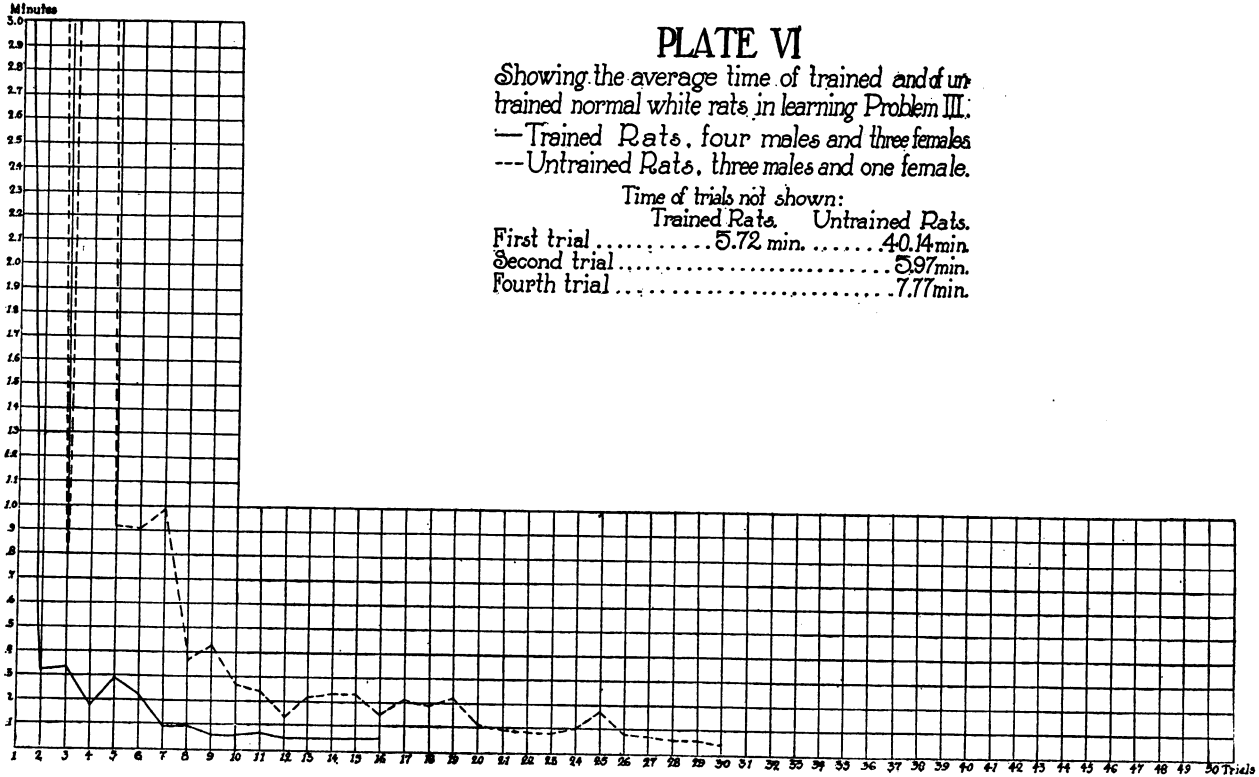


TABLE XIV.

Showing the average time-records of trained and of untrained normal black-and-white rats on Problem III. The first column gives the averages of the trained animals; the second, the third, and the fourth, give respectively the averages, the minimum, and the maximum time-records of the untrained animals.

NO. OF TRIAL.	AVERAGE.	AVERAGE.	MINIMUM.	MAXIMUM.
	min.	*min.*	*min.*	*min.*
1	.99	7.09	1.62	12.65
2	.49	4.97	3.42	6.42
3	.12	1.23	.72	1.70
4	.29	2.76	.32	4.25
5	.09	9.15	.40	25.78
6	.11	.76	.43	1.33
7	.07	2.44	.20	6.63
8	.04	.67	.41	.87
9	.08	1.35	1.00	1.95
10	.06	.57	.18	1.28
11	.14	.21	.11	.28
12	.04	.23	.18	.28
13	.05	.80	.07	1.42
14	.07	.15	.07	.27
15	.04	.18	.13	.22
16	.07	.21	.13	.32
17	.04	.12	.08	.17
18	.04	.10	.03	.17
19	.06	.14	.09	.22
20	.08	.14	.05	.28
21	.09	.08	.07	.08
22	.05	.07	.04	.18
23	.04	.10	.05	.10
24	.04	.08	.05	.07
25	.04	.05	.04	.09
26	.04	.07	.05	.08
27	.03	.09	.07	.12
28	.05	.10	.05	.15
29		.08	.07	.10
30		.06	.05	.07
31		.04	.03	.07
32		.06	.04	.08
33		.05	.04	.06
34		.04	.03	.08
35		.07	.04	.11
36		.05	.04	.06
37		.05	.07	.06
38		.07	.06	.06
39		.05	.04	.05
40		.06	.05	.07

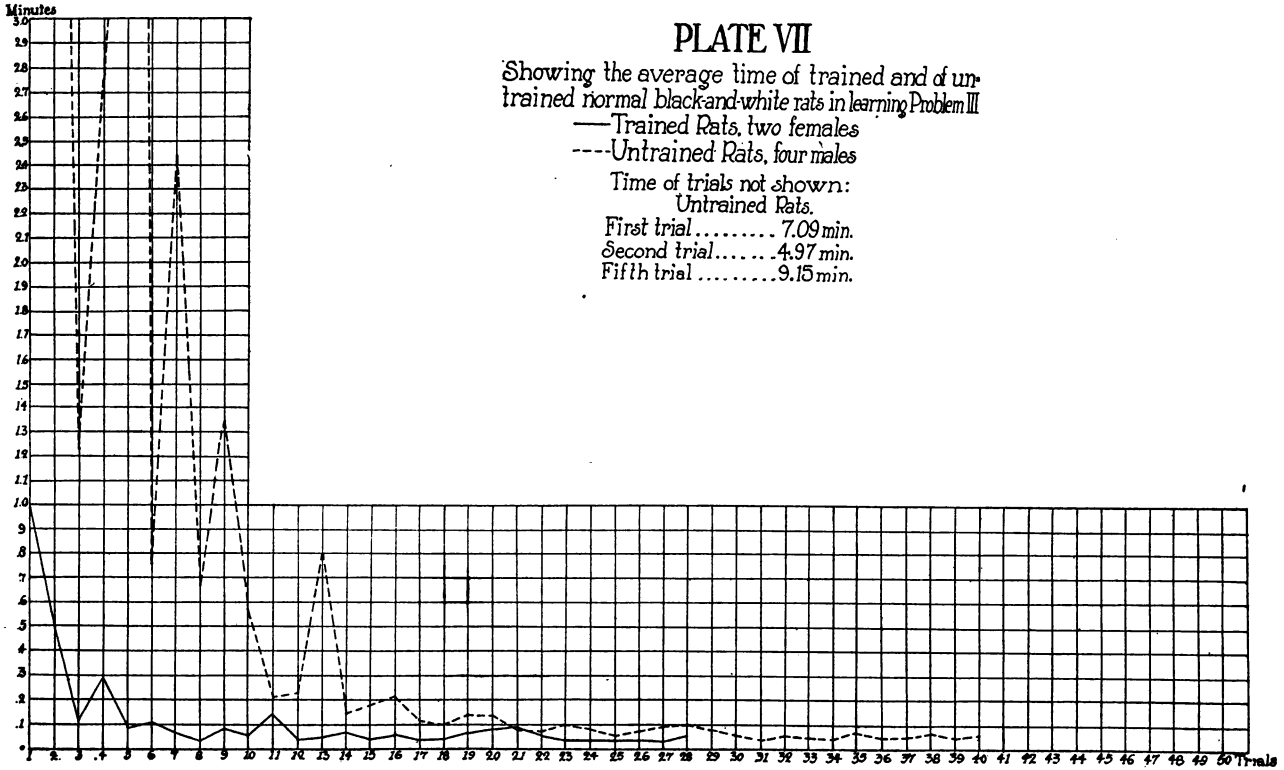
PLATE VII

Showing the average time of trained and of untrained normal black-and-white rats in learning Problem III

——Trained Rats, two females

----Untrained Rats, four males

Time of trials not shown:
Untrained Rats.
First trial.....7.09 min.
Second trial.....4.97 min.
Fifth trial.....9.15 min.



The untrained animals were tame but naturally not so tame as the trained rats when they began on this problem.[1] Two of them were frightened by the opening of the door; one rat was particularly careful not to approach the door from the front, but came up to it cautiously from the left so as not to be too near when the door should fly back. The rats did not locate the position of the door at once as the trained animals had done. This is doubtless one cause of the very high averages up to the tenth trial, the other apparent cause being the avoidance of the door.

e. Blind Rats on Problem III.

The experimenter desired to complete the comparisons with a discussion of differences as shown in the records of the behavior of experienced and inexperienced blind rats on Problem III. When the records were assembled it was found that the individual and accidental variations were so high among the defective animals that the averages of so small a group would be valueless in a comparison. Table XV shows the time records for each individual.

At the time of the experiment, but three inexperienced blind rats were available. Of these one made exceedingly poor time records for the first ten trials of the series, and his generally poor records throughout were a marked variation. Another animal made uniformly poor records as compared with the experienced blind rats, while the third rat was by far the most active of the twelve blind rats that were experimented upon. His records represent a marked variation in the other extreme. Consequently, an average of the records of these three animals would be valueless as a basis for comparison with any other group.

[1] The untrained animals were all of one litter, were 110 days old, and were of the same parentage as the litter of trained rats. The mother of the rats was the most active and energetic animal that had been tested in any of the experiments.

TABLE XV.

Showing the individual time-records of three untrained blind rats on Problem III.

NO. OF TRIAL.	MALE I.	FEMALE I.	FEMALE II.
1	4.77	6.32	6.47
2	1.45	15.72	1.30
3	.28	.35	.65
4	.28	1.87	.28
5	.18	4.17	3.50
6	.30	5.13	1.03
7	.12	6.37	.53
8	.15	5.53	.97
9	10.15	12.73	.80
10	.18	18.55	.65
11	.12	15.98	.90
12	.13	12.42	.42
13	.12	1.08	1.45
14	.13	.45	1.33
15	.12	.20	3.50
16	.08	10.98	1.10
17		1.87	1.95
18		.27	1.17
19		1.25	2.28
20		1.57	1.92
21		.25	2.58
22		.28	.88
23		1.60	.78
24		1.02	.05
25		.27	1.32
26		1.56	1.95
27		.17	1.87
28		.20	1.28
29		.37	.75
30		1.38	.68
31		.57	1.11
32		.27	.53
33		.93	.43
34		.32	.60
35		.17	.75
36		.22	
37		.37	
38		.08	
39		.45	
40		.28	

2. Summary of Facts Brought Out in Foregoing Experiments.

The comparison of the time-records and of the learning curves of each group of untrained rats with a group corresponding in age, variety (albino, or black-and-white), and condition (normal or defective) show that in every instance—with the possible exception of the case of the blind rats which cannot be cited as either confirmatory or contradictory—the trained animals made uniformly better records than the corresponding groups of untrained rats.[1]

II. CONCLUSIONS.

In view of the differences exhibited between the curves of the several groups of trained and untrained animals, it seems advisable to analyze the experience acquired in the solution of the previous problems. The first consideration is the effort to formulate a statement of: (1) What experience the animal acquires in the previous series of tests, and (2) what effects may be carried ever from one situation to another. Such a carrying over might result either in a transfer or an interference of training. The curves apparently justify the statement that, within the limits of such problems as were here employed, those rats which had had previous experimental experience were more apt in learning a new problem. Trained animals not only acquire the requisite association in a less number of trials but the early time-records are shorter. Expressed in terms of the neurological and physiological organism, the shorter time-record might be the result of a modification of either the motor or sensory system, or both. If the modification were one affecting the motor centers of the cortex and the efferent pathways, the stimulus might (1), release a greater amount of innervation, resulting in greater general activity, or (2), release movements which had become habitual in the earlier experience, and which would be advantageous in the attempts to solve the new problem, i. e., fewer random movements, and an earlier accidental success would result. If the modification

[1] Yerkes (*The Dancing Mouse*, p. 263) found that the acquisition of one labyrinth habit facilitated the acquisition of others.

were one affecting the sensory pathways and centers, the general result would be (1) an increased susceptibility to the stimulus—rendering the stimulus more intense—and (2) a decreased resistance in the connections between the sensory and motor centers, so that the indirect effect of the stimulus upon the musculature would be more immediate.

Observations of the behavior of the two groups of animals lead the writer to accept both of these possibilities as facts; that the stimulus is more intense and the activity more *immediate* and *better coördinated* in the case of the trained as against the untrained animal.

Previous to the work on Problem III, each rat had each day for thirty-four days been lifted from the door of its living cage, put through the door of the control cage upon the table and allowed to satisfy its hunger from food which had to be reached by its own exertions. It is reasonable to suppose that after such a long process of habituation to such experimental situations, the experience of being lifted from the living cage, carried to a distance and placed into another cage, might become for the rat a stimulus to activity when placed in the control cage.

In Problem II, given just previous to III, the entrance of the problem box occupied the same relative position, i. e., on the lower left-hand corner of the south side of the food box. When the trained rats were put into the cage containing Box III, they went to this position and began to 'nose' about. The contact sensations apparently released motor impulses which resulted in the scratching, biting, pulling and clawing at the spring, the latch, or the edge of the door. The first success soon followed. When the untrained rats were put into the cage, the environment was a stimulus to only the most general and uncontrolled activity. The rats examined the control cage as well as the box. They sniffed at the food and the latch, and then went on to examine other parts of the box and the cage. They often sat down to wash their faces and scratch themselves spending far more time at this procedure than did the trained animals. Motor energy in these animals, in the absence of any more specific stimulus, seemed to drain off into

these reflex channels. On the other hand all problem boxes (on account of past experience) served as potent stimuli to the trained rats; the animals had satisfied their curiosity as to the surroundings during previous tests and did not lack an incentive to effort in the present environment. Therefore in the case of the trained animals the stimulus released movements which were more advantageous in the solution of the problem than it did with the untrained animals.

The effect of the emotional attitude of the rat has been disregarded up to this point. The emotional element is a most important and ever present factor in the reaction of the animals. The rats, as stated before, were tame at the beginning of the experiments. They were accustomed to being handled and when the door of the cage was being opened, they came eagerly. At the end of the series this lack of timidity had advanced to a point that might be called familiarity. Instances of this were noted on a number of occasions when rats became ill or aged and refused food in their cages, they ate quite freely from food in the hands of the experimenter.

Accompanying the change in the emotional attitude of the rats toward the experimenter is the change in the emotional attitude toward the control cage and to problem boxes in general.[1] When this part of the environment which is common to all the tests has lost much of its novelty, there is nothing to interfere with the normal discharge of the impulses which will speedily result in adaptive movements. Because the situation as a whole is novel to the inexperienced rat, there is a state of high emotional tension in which motor impulses, foreign to the problem in hand, are set up by the strange sensory

[1] The same behavior as is here commented on as characteristic of trained animals was observed in the case of two brood rats which were bought from a small boy. These rats had absolutely no fear and exhibited no signs of disturbance when placed in strange experimental situations. The reactions of one of them which learned to jump a distance of 14 in. in the first day's test are described on page 76. The other rat solved Problem III in much less time than any other untrained rat. Her records are not included in the tables or curves as she was an old rat and did not conform to the age requirement for these tests.

These instances are cited in support of the contention that the emotional tone is a great (if not the greatest) factor in the ease with which the rat adapts itself to a new situation.

impressions. In the case of experienced rats no such outburst of motor energy is incident upon their introduction to a new problem; consequently they are in a better position to begin work immediately upon the elements in the situation which are novel.

B. INDIVIDUAL AND SEX DIFFERENCES AS SHOWN BY BEHAVIOR.

1. *Sex Differences.*

All of the tables giving the percentages of minimum and of maximum time-records made by each animal (such as are shown on p. 12) have been assembled and the following table compiled from the total number. The animals are ranked 1, 2, 3, etc., according to the percentage of maximum and of minimum time-records. For instance, the rat which made the greatest number of minimal trials is ranked 1; the rat with the next greatest number is ranked 2. The rat ranked as 1 in the portion of the table showing the rank in maximum time records, is consequently the animal making the greatest number of maximum, or poor time-records. The table is shown on next page.

The tabulation is of interest, showing as it does the comparative ranks of the animal in the different problems. It is rather striking that the greatest number of minimal records made in mixed groups are, with one exception, to the credit of the males, while in such groups the greatest number of maximal records are made by the females.[1] The least number of minimal records, with one exception, were made by females and the least number of maximal records were made by males. The records are not a sufficient basis for any general statement as to sex differences.

It is often, but not always true, that an animal which makes a good record on one problem makes good records on the other two. The ranking of the group of black-and-white rats on Problem I and II are striking.

[1] This is not true in Watson's work on the maze, in which the shortest records were made by the females. Yerkes (*Dancing Mouse*, p. 276) also found that the females were superior to the males in the labyrinth test, although the males were superior in discrimination tests.

Table showing sex and comparative rank of each animal in number of minimal and of maximal time-records on Problems I, II, and II.

	MINIMUM.				MAXIMUM.		
PROBLEMS.	I.	II.	III.	PROBLEMS.	I.	II.	III.
Normal White Rats.				*Normal White Rats.*			
Male I.....	1	3	1		3	3*	0
Male II.....	3*	1	3*		4	5	0
Male III....	2	5	3*		5*	4	3
Male IV....	3*	6	2		2	3*	2
Female I...	7	0	0†		1	0†	0†
Female II..	4	4	0		6	5	1
Female III.	6	2	0		5*	1	3
Female IV..	5	7	0¶		4	2	0¶
Normal Black-and-White Rats.				*Normal Black-and-White Rats.*			
Female I....	1	1	0¶		4	2	0¶
Female II...	3	3	0¶		3	4	0¶
Female III..	2	3	2		2	3	1
Female IV..	4	4	1		1	1	2
Blind Rats.				*Blind Rats.*			
Male I.....	0†	0	0‡		0†	0‡	0‡
Male II.....	1	0	0†		5*	0†	0†
Male III....	3	0	0¶		4	0¶	0¶
Male IV....	4	6	1		6	3	3
Female I...	7	5	0¶		1	1	0¶
Female II...	2*	4	0¶		3	2	0¶
Female III.	2*	3	0¶		5*	5	0¶
Female IV..	6	1	2		2	4	2
Female V...	5	2	3		5*	6	1

* *Two or* more animals attained the same rank in these cases.
† Records not included in averages but given under individual variations.
‡ Would not learn problems.
¶ Died before completing tests.

2. *Individual Differences.*

The following records of individuals are those which, for the reasons given, were not included in the averages of the groups, but are appended here for the purpose of comparison with the average records of the group.[1]

PROBLEM I.

Blind Male I made 72 per cent of the total number of maximal records, although he made 10 per cent of the minimal records. After the twenty-ninth trial, this rat made every maximal record. From the twelfth to the twenty-fourth trial, his records were unusually long, but after the twenty-fourth his behavior was such as to render his records incomparable with those of the other blind rats. He was slow and made errors repeatedly. The animal seemed timid in getting down from the top of the box. He was generally disturbed by the experimentation, and would crouch and quiver when the experimenter handled him. He became more nervous and irritable as the tests proceeded.

PROBLEM II.

Normal White Female I was the slowest of the group of eight normal white rats which were tested upon Problem I. She was also the slowest of the group on Problem II, and here her time-records represented a much wider variation than in Problem I. In the second problem she was slow in her movements and did not associate the act of stepping out on the plane with the falling of the door of the food box. Between the twentieth and thirtieth trials she established the habit of biting at the string which connected the plane with the latch of the door. She did not always go at once to the string and often she made several efforts,—at one time six—before she exerted sufficient force to throw it. These two causes of her long records, as may be seen, made the results too variable to be included in the average. In Problem III. her records were even more irregular.

[1] Yerkes (*ibid.*, p. 264 ff.) found wide and important individual variations among his mice.

Blind Male I, the records of which on Problem I have already been shown separately and commented upon, would make no effort to solve Problem II, and as he seemed to suffer from great timidity, the test was abandoned after five days.

Blind Male II was an active, healthy animal, and solved the problem well in his first efforts and seemed to have established the association by the twentieth trial, when he became disturbed by the falling plane,—evidently its noise—and thereafter he avoided it. When he stepped upon it at all, he did not step heavily enough to open the door. He made many trips to the plane, then to the door; then to the plane again, and finally, when his efforts were entirely too erratic to be useful, the test was discontinued.

PROBLEM III.

Normal White Female II made the maximum time-record for the group at every trial. She was slow in her movements and in addition often opened the latch while leaning downward over the door from the top of the box. She sometimes opened the door from the floor of the cage, but never until after she had spent some time on the box. Consequently, her records are given separately. In this problem as in the one previous, she did not learn to solve the problem in the manner which was customary for the other animals.

Blind Male II, which was not entirely successful in Problem II did not in this problem reduce his records to an approximate constancy even after fifty trials. His early time-records were both exceedingly long and variable. The cause of the poor records, as before, was slowness of movement, probably the effect of his timidity. The sudden opening of the door frightened him at the first trial, and he crouched motionless for half a minute before he seemed to regain courage to move about the cage. He avoided the locality of the door quite consistently for many trials, and when he finally went to the door, his movements were so slow and cautious the time-records were incomparable with those of the other blind rats. At the end of a series of 78 trials, his time-records were still long and variable.

TABLE XVI.

Showing Individual Differences on the Various Problems.

NO. OF TRIAL.	PROBLEM I.	PROBLEM II.		PROBLEM III.	
	Blind Male I.	Normal White Female I.	Blind Male I.	Normal White Female I.	Blind Male I.
1	6.02	2.55	.45	16.05	5.33
2	1.63	.73	.19	74.25	5.37
3	1.57	.63	1.58	1.45	16.82
4	1.27	.25	.35	.92	2.58
5	1.83	.13	.02	1.00	.85
6	1.17	3.52	.58	1.45	13.42
7	.37	.75	.43	1.42	11.92
8	.08	.73	5.60	.36	10.50
9	.98	9.08	1.70	.25	5.03
10	.27	1.55	3.83	.22	11.65
11	1.02	1.53	.48	.30	7.28
12	.78	1.77	5.12	1.73	4.88
13	.11	10.62	.30	.29	6.53
14	.15	1.27	6.12	.28	1.13
15	.17	.88	3.62	.33	4.32
16	.37	.22	4.20		2.30
17	.12	.45	2.17		5.78
18	.10	.33	3.15		3.37
19	.33	.17	1.03		1.47
20	.15	.13	5.75		2.05
21	.25	.50	2.10		3.47
22	.15	.17	2.13		.75
23	.43	.04	6.28		.42
24	.18	.05	6.33		.37
25	.15	.07	2.10		1.05
26	.85	1.28	4.67		.30
27	2.62	.31	2.55		.53
28	1.45	.67	2.87		.87
29	.13	.42	5.25		1.17
30	1.79	.22	2.82		.70
31	.58	1.58	6.23		.15
32	.50	3.75	.72		.25
33	.59	.65	3.08		.20
34	1.90	1.28			.70
35	3.08	.48			.62
36	.78	.15			.45
37	.62	.33			.60
38	1.72	.40			.68
39	1.30	1.22			.53

TABLE XVI.—Continued.

	PROBLEM I	PROBLEM II		PROBLEM III	
	Blind Male I.	Normal White Female I.	Blind Male I.	Normal White Female I.	Blind Male I.
40	1.47	1.05			.42
41	2.68	.65			.85
42	.74	.90			1.52
43	1.16	.98			.97
44	1.13	1.35			.72
45	1.66	.52			.72
46	.65	.38			1.38
47	.67	.27			.58
48	.62	.73			1.85
49	.78	1.30			1.17
50	.37	1.73			.85

PART THIRD

GENERAL CONCLUSIONS.

The following paragraphs summarize briefly and schematically the different conclusions drawn from the results of the experiments above described:

1. No positive evidence has been revealed as to the comparative acuity of vision in animals with albino eyes and those with pigmented eyes.

2. The tests with three problem-boxes requiring manipulation for solution afforded no conclusive evidence of the function of the visual impulses in the successful activities of the rats. The lack of vision, however, was disadvantageous in proportion as the problem demanded finely coördinated and narrowly localized movements.

3. In the test which necessitated a jumping reaction on the part of the animal, the visual stimulus apparently afforded a basis for the proper control as to the *direction* in which the jump was to be taken, but failed signally to afford any adequate basis for accommodating to changes in distance only. The visual impressions were not a sufficient control when the length of the jump was changed and after a seeming struggle between visual and kinæsthetic factors, the coördination broke down completely. Blind animals learned to jump considerable distances, but they were first given their orientation.

4. Olfactory stimulations had evidently little importance in the problems here utilized. Such impressions were quite as likely to interfere with, as to guide the formation of, the requisite habit.

5. Tactual impressions, noticeably from the vibrissæ,